REVISTA DE Biología Tropical

Essential oils of *Baccharis trinervis* (Asteraceae) from Costa Rica

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Received 11-V-2017. Corrected 20-VII-2017. Accepted 23-VIII-2017.

Abstract: *Baccharis* is an Asteraceae genus of flowering plants, which has about 340 to 400 species, ranging from the Southern United States to the Southern extreme of Argentina and Chile through Central America and the Caribbean regions. The species *Baccharis trinervis* is a native shrub from Mexico, Central America and throughout South America. In Costa Rica, this species is commonly known as *alcotán* and the fresh leaves are used as a poultice on wounds and ulcers. The objective of the present research was to characterize the chemical composition of seven hydrodistilled essential oils of diverse morphological parts of *B. trinervis*. For this, samples were obtained from three locations in Costa Rica and standard laboratory analyses were followed. The essential oils were analyzed by capillary gas chromatography-flame ionization detector (GC-FID) and gas chromatography-mass spectrometry (GC-MS) using the retention indices on a 5 % phenyl/dimethylpolysiloxane fused silica column in addition to mass spectral fragmentation patterns, which allowed the identification of 268 compounds. The essential oils consisted mainly of terpenoids (92.3 to 97.8 %). The major constituents from the leaf oils were caryophyllene oxide (0.1-22.5 %), viridiflorol (8.8-21.0 %), germacrene D (0.5-19.1 %), germacrene B (0.2-16.0 %), β-caryophyllene (3.5-9.1 %), spathulenol (0.1-8.3 %), δ-3-carene (2.0-6.8 %), and α-pinene (2.5-5.9 %). The flower oil consisted mainly of globulol (0-24 %), β-caryophyllene (9.5-17.1 %), *cis*-muurola-4(14), 5-diene (traces-13.7 %), germacrene D (4.3-9.9 %), bicyclogermacrene (5.9-8.3 %), *ar*-curcumene (0-8.0 %), spathulenol (4.3-4.8 %), caryophyllene oxide (3.1-4.7 %), and viridiflorol (0.3-4.7 %). The major components of the branch oil were germacrene B (1.4-18.7 %), germacrene D (14.7-15.6 %), β-caryophyllene (10.1-12.4 %), viridiflorol (0-11.5 %), globulol (0.6-11.3 %), δ-3-carene (4.1-8.1 %), β-phellandrene (1.5-6.5 %), and bicyclogermacrene (3.6-4.9 %). The essential oil composition differed markedly from that of previously studied oils of plants growing in Brazil, which contain two characteristic stereoisomeric methyl dec-2-en-4,6-diynoate compounds not detected in this study. This is the first report about the chemical composition of the essential oils obtained from this species growing wild in Costa Rica. Rev. Biol. Trop. 65 (4): 1307-1321. Epub 2017 December 01.

Key words: *Baccharis trinervis*, Asteraceae, essential oils, terpenoids, GC-MS, Costa Rica.

Baccharis L. is one of the largest genera within Asteraceae family (tribe Astereae, sub-tribe Baccharidinae) including herbaceous perennials, vines, shrubs and trees. This genus includes ca. 340 to 400 species ranging from the Southern United States to the Southern extreme of Argentina and Chile through Central America and the Caribbean basin (Heiden, Andrade-Baumgratz, & Esteves, 2012). Some of the species are economically important as medicinals -used mainly as infusions and decoctions- for treat stomach and liver ailments, inflammations, anemia, diabetes and prostate diseases (Verdi, Brighente, & Pizzolatti, 2005). The vassoura essential oil (*Baccharis dracunculifolia* DC.) and carqueja oil [*B. genistelloides* (Lam.) Pers.] are used in perfume industry (Ferracini et al., 1995).

Baccharis trinervis Pers. [=*Pseudobaccharis trinervis* (Pers.) V. M. Badillo] is a common shrub or sub-scandent shrub in the Pacific slope of Costa Rica, with hairless ribbed stems

and oblong-elliptic or lanceolate-elliptic alternate leaves, 3 to 10 cm long, 1.5 to 3.5 cm wide, hard and rough, with three prominent, longitudinal veins, puberulent to pilose on both sides. Flowers are greenish-white disposed in terminal panicles (León & Poveda, 2000) situated within or overtopping the foliage. This plant has a wide distribution, from Mexico, Central America and throughout South America. In Costa Rica it is distributed over the country, from lowlands to 1 900 m of elevation, in both dry and wet forests. This plant is commonly known as *alcotán*, and in the Northwestern Guanacaste Province it is known as *jalapatrás* and *rastrapo* (León & Poveda, 2000). In Costa Rica, the fresh leaves are used as a poultice on wounds and ulcers (Pittier, 1978) and the alcoholic extracts of roots are said to be used as remedy for snakebites (Núñez-Meléndez, 1978). In Honduras, the extracted juice of the leaf, and root decoctions, are taken as a remedy for kidney troubles, pain and inflammations, as a febrifuge, for halting diarrhea, and against rheumatic pains (House et al., 1995). It has also been used in various liver diseases, as a purgative, antiseptic, digestive and diuretic, in rectal washes against hemorrhoids and as a remedy for typhoid fever (Ramírez-Cárdenas, Isaza-Mejía, & Pérez-Cárdenas, 2013).

Many phytochemical investigations have been performed on plants of the *Baccharis* genus and are characterized by the occurrence of flavonoids, diterpenoids (the most prominent classes are clerodanes and labdanes, and with some frequency, kauranes), triterpenes, phenolic compounds, and particularly important is the occurrence of essential oils (Verdi et al., 2005; Abad & Bermejo, 2007; Ramos Campos et al., 2016). From the aerial parts of *Baccharis trinervis*, Bohlmann and Zdero (1970) reported the presence of matricaria ester, and three C-17 esters with an ene-diyne-diene-structure. From air-dried aerial parts (from Brazil) were obtained the terpenoids phytene, caryophyllene, germacrene D, bicyclogermacrene, α- and γ-humulene, squalene, lupeyl acetate, lupeol, β-amyrin and the diacetylenic compound lachnophyllum ester (Bohlmann, Kramp, Grenz, Robinson, & King, 1981), whereas the study of Kuroyanagi, Uchida, Ueno, Satake, and Shimomura (1993) afforded 24 *neo*-clerodane type diterpenes, many of them new. Also, Herrera, Rosas-Romero, Crescente, Acosta, and Pekerar (1996) reported several 5-hydroxy-7-methoxyflavones from leaves, and Sharp et al. (2001) reported three 6-oxigenated flavones from branches.

Regarding biological activities attributed to this species there are some reports about antioxidant activity of the ethanolic extract (Heras et al., 1998), antiviral activity against herpes simplex type I (HSV-1), vesicular stomatitis virus (VSV-1) and poliovirus type I (Abad, Bermejo, Sánchez-Palomino, Chiriboga, & Carrasco, 1999), anti-HIV activity in macrophages (Sánchez-Palomino et al., 2002), antimicrobial activity (Albuquerque et al., 2004), and antioxidant, antifungal and hemolytic activities of the essential oil (Sobrinho et al., 2016).

In relation to the essential oil composition of the aerial parts of this species, there are only three previous reports: two studies from material collected in the state of Ceará, Northeast Brazil (Albuquerque et al., 2004; Sobrinho et al., 2016), and another from the state of Mérida, Venezuela (Rojas et al., 2008).

The objective of the present research was the characterization of the chemical composition of seven different samples of essential oils from diverse morphological parts of *B. trinervis* collected in three different locations in central Costa Rica. To the best of our knowledge, no previous chemical work on *B. trinervis* from Costa Rica has been reported.

MATERIALS AND METHODS

Plant material: The aerial parts of *Baccharis trinervis* were collected from three localities of Costa Rica: Miramar, Montes de Oro mountains (west central Pacific), Province of Puntarenas (10°06'12.79" N - 84°42'26.09" W, at an elevation of 750 m), on April 2009, during the flowering stage; in the University of Costa Rica Campus, San Pedro de Montes de Oca, Province of San José (9°56'14.60" N - 84°02'51.51" W,

at 1 210 m elevation), on February 2009, during vegetative stage, and Pavas, Province of San José (9°56'37.20" N - 84°06'59.40" W, at an elevation of 1 093 m) on November 2015, during the flowering stage of the plant. A voucher specimen has been deposited in the Herbarium of the University of Costa Rica at the School of Biology (USJ 93916).

Isolation of the essential oils: Plant materials were hydrodistilled at atmospheric pressure, for 3 h, using a Clevenger-type apparatus. The distilled oils were collected and dried over anhydrous sodium sulfate, filtered and stored at 0-10 °C in the dark, for further analysis. The essential oil yields (v/w) from diverse morphological parts from three localities in central Costa Rica were: Miramar sample, 0.32 % (leaf), 0.04 % (flower); San Pedro sample, 0.35 % (leaf), 0.03 % (branch); and Pavas sample, 0.23 % (leaf), 0.06 % (flower), and 0.05 % (branch).

Gas chromatographic (GC-FID) analyses: The oils of *Baccharis trinervis* were analyzed using a Shimadzu GC-2014 gas chromatograph. The data were obtained on a 5 % phenyl/dimethylpolysiloxane column (30 m x 0.25 mm; film thickness 0.25 μm), (MDN-5S, Supelco), with a Shimadzu GCsolution Chromatography Data System, Shimadzu GC Solution, Chromatography Data System, software version 2.3. The experimental conditions were: carrier gas N_2, flow 1.0 mL/min; oven temperature program: 60 to 280 °C at 3 °C/min, 280 °C (2 min); sample injection port temperature 250 °C; detector temperature 280 °C; split 1:60.

Gas chromatography-mass spectrometry (GC-MS): The analyses were performed using a Shimadzu GC-17A gas chromatograph coupled with a GCMS-QP5000 apparatus and CLASS 5000 software with Wiley 139 and NIST computer databases. The data were obtained on a MDN-5S column (30 m x 0.25 mm), coated with 5 % phenyl/dimethylpolysiloxane (film thickness 0.25 μm). Experimental conditions were: carrier gas He, flow 1.0 mL/min; oven temperature program: 60 to 280 °C at 3 °C/min; sample injection port temperature 250 °C; detector temperature 260 °C; ionization voltage: 70 eV; ionization current 60 μA; scanning speed 0.5 s over 38 to 400 amu range; split 1:70.

Compound identification and quantification: The components of the oils were identified by comparison of their linear retention indices which were calculated in relation to a homologous series of *n*-alkanes, on 5 % phenyl/ dimethylpolysiloxane type column (van den Dool & Kratz, 1963), and by comparison of their mass spectral fragmentation patterns with those published in the literature (Adams, 2007) or those of our own database. To obtain the retention indices for each peak, 0.1μL of *n*-alkane mixture (Sigma, C_8 to C_{32} standard mixture) was injected under the same experimental conditions reported above. Integration of the total chromatogram (GC-FID), expressed as area percent, has been used to obtain quantitative compositional data without FID response factor correction.

RESULTS

The essential oils from different parts of *Baccharis trinervis* from Costa Rica presented a very complex chemical profile. The compounds identified, their experimental retention indices (RI) determined in relation to a homologous series of linear alkanes (C_8 to C_{32}), their relative percentage concentrations, and the method used for their identification are presented in table 1. The constituents are listed in order of elution on a MDN-5S column and for comparison purposes, previously published values of the retention indices are included (Lit. RI). Compounds identified in this study and previously reported in the Venezuelan and Brazilian essential oil samples are indicated by bullets and/or asterisks.

Baccharis trinervis gave essential oils which were predominantly terpenoid in nature with a few aliphatic and aromatic compounds as minor and trace constituents. In table 2,

TABLE 1
Chemical and percentage composition of oils of *Baccharis trinervis* from three locations in Costa Rica

Compound[a]	RI[b]	Lit. RI[c]	Class[d]	Miramar		San Pedro		Pavas			Ident. method[e]
				Leaf	Flower	Leaf	Branch	Leaf	Flower	Branch	
Hexane	623	623	A	t							1,2,3
3-Methylbutanal	655	658	A	t							1,2
2-Ethylfuran	702	702	Misc.	t							1,2
Pentanal	704	704	A			t	0.1				1,2
4-Methylcyclohexene	740	740	A			t					1,2
Toluene	768	770[f]	B	t							1,2
Octane	800	800	A	t							1,2,3
Hexanal	801	801	A		t		t				1,2
(*E*)-Hex-2-enal	852	846	A	t	t	t	t	0.1		0.1	1,2
(*Z*)-Salvene	846	847	M	t							1,2
(*E*)-Hex-2-en-1-ol	859	854	A			0.1		0.2		0.1	1,2
Hexan-1-ol	864	863	A		t	0.1		t		t	1,2
2-Butylfuran	883	885[g]	Misc.		t						1,2
Heptan-2-one	888	889	A		t						1,2
(*Z*)-Hept-4-enal	897	898	A		t						1,2
Heptanal	901	901	A	t	0.1	t	t	t		t	1,2
α-Thujene*•	923	924	M	1.0	0.3	1.7	0.3	1.6	0.1	0.3	1,2
α-Pinene*•	930	932	M	3.9	1.0	2.5	0.6	5.9	0.3	1.9	1,2,3
Camphene*•	946	946	M	0.1	t	0.1		0.1		t	1,2
Thuja-2,4(10)-diene	952	953	M	t							1,2
Benzaldehyde	959	952	B	t	t	t					1,2
Sabinene*•	970	969	M	0.8	0.3	0.4	0.2	1.6	0.3	0.3	1,2
β-Pinene*•	978	974	M	1.6	1.0	1.3	0.8	2.5	0.4	2.1	1,2,3
6-Methylhept-5-en-2-one	982	981	A	t				t			1,2
Myrcene*•	986	988	M	0.2	0.3	0.8	0.5	1.3	0.1	1.4	1,2
Dehydro-1,8-cineole	988	988	M	0.1							1,2
Mesitylene	995	995	B					t			1,2
Decane	1 000	1 000	A		t				t		1,2,3
δ-2-Carene	1 000	1 001	M	t	t	t		t	t		1,2
α-Phellandrene*	1 002	1 002	M					0.1			1,2
p-Mentha-1(7)-8-diene	1 003	1 003	M	t							1,2
(*Z*)-Hex-3-en-1-yl acetate	1 004	1 004	A	t	0.1						1,2
(*E*)-Hex-2-en-1-yl acetate	1 007	1 010	A		t						1,2
δ-3-Carene*	1 008	1 008	M	2.0	0.9	6.8	4.1	6.6	2.2	8.1	1,2
α-Terpinene*	1 016	1 014	M	t	0.1	0.2	0.1	0.1	t	0.4	1,2
p-Cymene*	1 020	1 020	M		t	0.1		t	t		1,2
o-Cymene	1 022	1 022	M	0.1	0.1			0.8	0.2	0.4	1,2
Limonene*	1 026	1 024	M	0.9	0.6	0.9	0.7	2.9	0.6	1.5	1,2,3
β-Phellandrene*•	1 027	1 025	M	0.1	0.5	1.9	1.5	1.0	0.3	6.5	1,2
1,8-Cineole	1 031	1 026	M		t						1,2,3
(*Z*)-β-Ocimene*•	1 036	1 032	M	0.1	t	t		t	t	t	1,2
(*E*)-β-Ocimene*•	1 043	1 034	M	t	0.1	0.5	0.3	0.1	t	1.0	1,2
γ-Terpinene*•	1 056	1 054	M	t	0.1	0.9	0.3	t	0.1	1.1	1,2
(*E*)-Oct-2-en-1-ol	1 063	1 060	A		t						1,2
cis-Sabinene hydrate•	1 068	1 065	M	0.1	0.2			t			1,2
cis-Linalool oxide (furanoid)	1 074	1 067	M						0.2		1,2
m-Cymenene	1 079	1 082	M	t	t						1,2

TABLE 1 (Continued)

Compound[a]	RI[b]	Lit. RI[c]	Class[d]	Miramar		San Pedro		Pavas			Ident. method[e]
				Leaf	Flower	Leaf	Branch	Leaf	Flower	Branch	
p-Mentha-2,4(8)-diene	1 080	1 085	M			t		0.1			1,2
Terpinolene*	1 084	1 086	M	t	0.1	1.0	0.6	t	0.2	1.5	1,2
p-Cymenene	1 089	1 089	M	t	0.1	t	0.1			0.2	1,2
Linalool*	1 094	1 095	M	0.3	0.1	t	t	0.1	0.1		1,2,3
trans-Sabinene hydrate•	1 099	1 098	M	0.1		t		0.1			1,2
Undecane	1 100	1 100	A							t	1,2
Nonanal	1 101	1 100	A	t	0.2		t	t	t	t	1,2
Perillene	1 104	1 102	Misc		t		0.1	t	t	1.0	1,2
α-Fenchocamphorone	1 109	1 104	M	t							1,2
(*Z*)-2-Isopropyl-5-methyl-hex-2-enal	1 112	1 112	A		t						1,2
trans-Thujone	1 113	1 112	M	t							1,2
Dehydro-sabina ketone	1 116	1 117	M	0.1							1,2
cis-*p*-Menth-2-en-1-ol*•	1 122	1 118	M		0.1	0.1	t	0.2	t	0.1	1,2
α-Campholenal	1 123	1 122	M	0.1							1,2
(*E*,*E*)-2,6-Dimethyl-1,3,5,7-octatetraene	1 128	1 130 [h]	M			t				t	1,2
cis-Limonene oxide	1 131	1 132	M	0.1				t	0.1		1,2
cis-*p*-Mentha-2,8-dien-1-ol	1 133	1 133	M				t				1,2
trans-Pinocarveol	1 135	1 135	M	t	0.1						1,2
trans-*p*-Menth-2-en-1-ol	1 136	1 136	M			t		0.1		t	1,2
trans-Sabinol	1 136	1 137	M	t							1,2
cis-Pinene hydrate	1 139	1 139	M						t		1,2
(*E*)-Tagetone	1 139	1 139	M	0.3							1,2
trans-Verbenol	1 144	1 140	M		t				0.1		1,2
p-Meth-3-en-8-ol	1 148	1 145	M	0.2							1,2
Eucarvone	1 148	1 146	M	0.2							1,2
neo-*iso*-Thujan-3-ol	1 149	1 147	M				t				1,2
Nerol oxide	1 150	1 154	M			t		t			1,2
neo-Thujan-3-ol	1 153	1 149	M	t							1,2
(*E*)-Non-2-enal	1 157	1 157	A		t		t				1,2
Benzyl acetate	1 158	1 157	B	0.1							1,2
trans-Pinocamphone	1 160	1 158	M						0.1		1,2
δ-Terpineol	1 161	1 162	M		0.2						1,2
(2Z)-Non-2-en-1-ol	1 163	1 162	A						0.1		1,2
1,3-Dimetoxibenzene	1 165	1 165	B		0.1						1,2
Borneol	1 165	1 165	M	0.1		t					1,2
p-Mentha-1,5-dien-8-ol	1 167	1 166	M		t		t	t	t		1,2
Santolinyl acetate	1 173	1 171	M							t	1.2
cis-Pinocamphone	1 175	1 172	M	0.1	0.1						1,2
Terpinen-4-ol*•	1 177	1 174	M	0.7	0.1	0.5	0.3	0.7	0.1	0.8	1,2,3
p-Methyl acetophenone	1 182	1 179	B	t							1,2
p-Cymen-8-ol	1 184	1 179	M	0.4		t		0.7	0.1		1,2
Cryptone•	1 186	1 183	M		0.1	t	t	0.1			1,2
Dill ether	1 188	1 184	M						0.2		1,2
α-Terpineol	1 190	1 192[i]	M	0.5			t	0.1	0.1	0.2	1,2
Methyl salicylate	1 191	1 190	B			t	t			t	1,2
Dihydrocarveol	1 192	1 192	M	t							1,2
Myrtenol	1 196	1 194	M		0.1						1,2
cis-Piperitol	1 198	1 195	M			t				t	1,2
Safranal	1 199	1 197	M	t							1,2

TABLE 1 (Continued)

Compound[a]	RI[b]	Lit. RI[c]	Class[d]	Miramar		San Pedro		Pavas			Ident. method[e]
				Leaf	Flower	Leaf	Branch	Leaf	Flower	Branch	
Dodecane	1 200	1 200	A						0.1		1,2,3
Verbenone	1 206	1 204	M	0.3	0.1						1,2
trans-Piperitol	1 207	1 207	M			t		t			1,2
(*E*,*E*)-Nona-2,4-dienal	1 209	1 210	A	t							1,2
4-Methylene-isophorone	1 216	1 216	M	t				0.1			1,2
β-Cyclocitral	1 217	1 217	M		0.1						1,2
cis-Sabinene-hydrate acetate	1 218	1 219	M			t				t	1,2
Citronellol	1 218	1 219	M			t					1,2
(*Z*)-Ocimenone	1 228	1 226	M		t						1,2
Nerol	1 230	1 227	M			t					1,2
(3*Z*)-Hexenyl 3-methylbutanoate	1 232	1 230	A							t	1,2
(3*Z*)-Hexenyl 2-methylbutanoate	1 232	1 232	A			t					1,2
Ascaridole	1 234	1 234	M					t			1,2
Cumin aldehyde	1 240	1 238	M		0.1						1,2
Carvone	1 241	1 239	M	0.2							1,2
(2*Z*)-Hexenyl 3-methylbutanoate	1 242	1 241	A					t			1,2
(2*E*)-Hexenyl 3-methylbutanoate	1 243	1 243	A					0.1		t	1,2
Car-3-en-2-one	1 245	1 244	M	0.1	0.1	t		0.1			1,2
Piperitone	1 249	1 249	M	0.1	t						1,2
Geraniol	1 250	1 249	M		t		t				1,2
trans-Ascaridol glicol	1 267	1 266	M					0.1			1,2
p-Menth-1-en-7-al	1 285	1 273	M		t					t	1,2
p-Ethyl acetophenone	1 285	1 279	B				t				1,2
Bornyl acetate	1 286	1 287	M	0.1	t						1,2
Thymol*	1 288	1 289	M	0.3							1,2
γ-Terpinen-7-al	1 289	1 291	M				t				1,2
Undecan-2-one	1 295	1 293	A		t						1,2
Tridecane	1 300	1 300	A		0.1				t		1,2,3
Undecanal	1 308	1 305	A		0.1				0.2		1,2
Dihydrocarveol acetate	1 309	1 306	M						t		1,2
Isoverbanol acetate	1 310	1 308	M					0.5			1,2
(*E*,*E*)-Deca-2,4-dienal	1 314	1 315	A		t		0.1				1,2
δ-Terpinyl acetate	1 319	1 316	M	t							1,2
(3*Z*)-Hexenyl tiglate	1 320	1 319	A					t			1,2
Silphiperfol-5-ene	1 323	1 326	S		0.1						1,2
cis-Piperitol acetate	1 331	1 332	M		0.2		t				1,2
δ-Elemene*	1 334	1 335	S		0.2	0.3	0.2	0.1	0.2	0.1	1,2
7-*epi*-Silphiperfol-5-ene	1 344	1 345	S			t	t		0.1		1,2
α-Cubebene	1 345	1 345	S	0.4	0.3	0.5	0.7	0.2		0.2	1,2
α -Terpinyl acetate*	1 347	1 346	M					0.2			1,2
α-Longipinene	1 357	1 350	S	t					0.1		1,2
Cyclosativene	1 366	1 369	S	0.5	t		t				1,2
α-Ylangene	1 369	1 373	S		0.4	0.3	0.5	0.4	0.3	0.3	1,2
α-Copaene*•	1 373	1 374	S	1.3	0.7	1.1	1.5	0.6	0.8	1.0	1,2
Silphiperfol-6-ene	1 377	1 377	S		0.2						1,2
β-Patchoulene	1 379	1 379	S	t							1,2
β-Cubebene	1 384	1 387	S		0.1	t		t	0.3	0.1	1,2
β-Bourbonene	1 386	1 387	S	t				0.2		0.1	1,2
β-Elemene*•	1 386	1 389	S	0.8	2.5	2.1	2.7	3.0	4.3	1.3	1,2

TABLE 1 (Continued)

Compound[a]	RI[b]	Lit. RI[c]	Class[d]	Miramar		San Pedro		Pavas			Ident. method[e]
				Leaf	Flower	Leaf	Branch	Leaf	Flower	Branch	
Tetradecane	1 400	1 400	A		t				t		1,2,3
β-Longipinene	1 401	1 400	S		0.1	t	0.1				1,2
Methyleugenol	1 403	1 403	PP	0.2		t					1,2
Longifolene	1 405	1 407	S			t	t				1,2
α-Gurjunene	1 409	1 409	S				t	0.2	0.1		1,2
β-Caryophyllene*•	1 416	1 417	S	3.5	9.5	9.1	12.4	7.9	17.1	10.1	1,2,3
β-Copaene	1 428	1 430	S	0.3	0.8	t	2.8	0.7	t	0.6	1,2
β-Gurjunene	1 429	1 431	S						0.7		1,2
α-*trans*-Bergamotene	1 432	1 432	S	t	0.1					0.1	1,2
γ-Elemene	1 432	1 434	S			1.9		t			1,2
α-Guaiene	1 434	1 437	S			0.1		0.1	0.1		1,2
Aromadendrene	1 437	1 439	S	t	0.1	0.2	0.1	0.3	0.1	0.2	1,2
(*Z*)-β-Farnesene	1 438	1 440	S	0.1	0.3						1,2
6,9-Guaiadiene	1 442	1 442	S			0.1	t	t	t		1,2
cis-Muurola-3,5-diene	1 447	1 448	S		t		t	0.2	t	0.1	1,2
trans-Muurola-3,5-diene	1 450	1 451	S			0.2	t	t		0.1	1,2
α-Humulene*•	1 453	1 452	S	0.5	2.2	1.0	1.3	1.1	1.8	1.4	1,2,3
(*E*)-β-Farnesene	1 454	1 454	S		t						1,2
Alloaromadendrene	1 458	1 458	S	0.1		0.1			0.1	0.1	1,2
cis-Cadina-1(6),4-diene	1 460	1 461	S			t				0.1	1,2
9-*epi*-β-Caryophyllene	1 461	1 464	S					0.1	t	t	1,2
cis-Muurola-4(14),5-diene	1 465	1 465	S		13.7		t	0.1	t		1,2
Dauca-5,8-diene	1 471	1 471	S	t							1,2
trans-Cadina-1(6),4-diene	1 471	1 475	S	t							1,2
γ-Gurjunene	1 477	1 475	S					t	0.6	0.3	1,2
γ-Muurolene*•	1 478	1 478	S				2.1	1.6		1.6	1,2
ar-Curcumene	1 471	1 479	S	2.0	8.0						1,2
γ-Curcumene	1 478	1 481	S	1.5							1,2
α-Amorphene	1 483	1 483	S	0.2			0.1				1,2
Germacrene D*	1 486	1 484	S	0.5	4.3	19.1	14.7	6.3	9.9	15.6	1,2,3
β-Selinene*	1 490	1 489	S		0.3	0.9	1.6	1.1	0.5		1,2
cis-β-Guaiene	1 493	1 492	S	0.6							1,2
trans-Muurola-4(14),5-diene	1 493	1 493	S		t	0.7		t			1,2
Viridiflorene	1 496	1 496	S				0.7			1.8	1,2
Bicyclogermacrene*•	1 498	1 500	S		8.3	4.4	3.6	2.5	5.9	4.9	1,2
α-Muurolene*	1 497	1 500	S	0.5			1.0	t		0.4	1,2
Epizonarene	1 502	1 501	S			0.7					1,2
trans-β-Guaiene	1 506	1 502	S		0.5						1,2
β-Bisabolene	1 505	1 505	S	0.4	1.4						1,2
Germacrene A	1 507	1 508	S			0.5	0.4	0.3			1,2
δ-Amorphene	1 510	1 511	S	0.1	0.4		0.4		0.5	0.3	1,2
γ-Cadinene*	1 513	1 513	S	0.3	2.5	0.6	0.8	0.5	0.3	0.5	1,2
Cubebol	1 515	1 514	S	2.5	0.3	0.1	t		t		1,2
β-Sesquiphellandrene	1 518	1 521	S		0.5						1,2
δ-Cadinene*	1 519	1 522	S	0.8		3.4	4.3	1.4	1.4	3.5	1,2
cis-Calamenene	1 526	1 528	S	0.3			0.2	t			1,2
Zonarene	1 527	1 528	S			0.1				0.1	1,2
(*Z*)-Nerolidol	1 533	1 531	S	0.1							1,2
trans-Cadina-1,4-diene	1 531	1 533	S	0.2	0.5	0.2	0.2	0.2			1,2

TABLE 1 (Continued)

Compound[a]	RI[b]	Lit. RI[c]	Class[d]	Miramar		San Pedro		Pavas			Ident. method[e]
				Leaf	Flower	Leaf	Branch	Leaf	Flower	Branch	
10-*epi*-Cubebol	1 535	1 533	S	0.1						0.3	1,2
α-Cadinene*	1 536	1 536	S		0.2	0.4	0.6	0.2	0.1		1,2
cis-Sesquisabinene hydrate	1 537	1 542	S					t			1,2
α-Calacorene	1 538	1 544	S	0.7	0.5			t	0.1	0.2	1,2
Selina-3,7(11)-diene	1 541	1 545	S			0.3	0.6				1,2
Hedycaryol	1 546	1 546	S					0.3			1,2
Elemol	1 547	1 548	S						0.2		1,2
trans-Dauca-4(11),7-diene	1 552	1 557	S				t				1,2
Silphiperfol-5-en-3-ol A	1 554	1 557	S	0.1							1,2
Germacrene B*	1 557	1 559	S	0.2	4.3	16.0	18.7	1.4	1.8	1.4	1,2
β-Calacorene	1 560	1 564	S	1.3					0.2	0.4	1,2
(*E*)-Nerolidol	1 567	1 561	S	0.2			0.1				1,2,3
Palustrol	1 569	1 567	S	0.3	0.1	0.1	0.2	0.4	0.4	0.4	1,2
Dendrolasin	1 570	1 570	Misc		0.1		0.1				1,2
(*Z*)-Dihydroapofarnesol	1 571	1 571	S		t					0.1	1,2
Spathulenol	1 577	1 577	S	8.3	4.3	0.1	0.2	3.0	4.8	0.3	1,2
Caryophyllene oxide	1 583	1 582	S	22.5	3.1	0.1	1.3	1.7	4.7	0.4	1,2
Thujopsan-2-α-ol	1 585	1 586	S				t				1,2
Globulol	1 590	1 590	S			0.1	11.3	0.3	24.8	0.6	1,2
Salvial-4(14)-en-1-one	1 593	1 594	S		t						1,2
Viridiflorol	1 594	1 592	S	20.3	4.7	8.8		21.0	0.3	11.5	1,2
Ledol	1 604	1 602	S	0.5		0.1	0.1	0.5		0.3	1,2
5-*epi*-7-*epi*-α-Eudesmol	1 606	1 607	S				t	0.6		0.5	1,2
Humulene epoxide II	1 608	1 608	S	2.5	1.2						1,2
1,10-di-*epi*-Cubenol	1 616	1 618	S			t				0.3	1,2
Junenol	1 622	1 618	S				t			0.4	1,2
1-*epi*-Cubenol	1 626	1 627	S	2.1	0.7	0.1	0.2	0.4		0.6	1,2
(*E*)-Sesquilavandulol	1 631	1 631	S	0.3							1,2
cis-Cadin-4-en-7-ol	1 634	1 635	S	1.6	3.5					0.5	1,2
epi-α-Cadinol (=T-Cadinol)*	1 641	1 638	S	0.3	1.1	0.3	0.4	1.3	0.7	t	1,2
epi-α-Muurolol (=T-Muurolol)	1 642	1 640	S		1.0	0.1	0.1	0.9	0.8	1.3	1,2
Cubenol	1 644	1 645	S		0.5						1,2
α-Muurolol (=Torreyol)*	1 645	1 644	S	0.5		t	t			0.4	1,2
α-Cadinol*	1 655	1 652	S		1.2	0.8	0.5	1.7	0.3	1.7	1,2
Selin-11-en-4-α-ol	1 658	1 658	S		t	0.1		0.5	1.1	0.4	1,2
neo-Intermedeol	1 660	1 658	S				0.3				1,2
cis-Calamenen-10-ol	1 663	1 660	S					0.3			1,2
Intermedeol	1 665	1 665	S				t			0.1	1,2
trans-Calamenen-10-ol	1 667	1 668	S					0.3	0.2		1,2
14-Hydroxy-9-*epi*-β-caryophyllene	1 668	1 668	S	1.3		t					1,2
Cadalene	1 672	1 675	S	t	0.4						1,2
Mustakone	1 672	1 676	S	0.5							1,2
Khusinol	1 679	1 679	S				t				1,2
epi-α-Bisabolol	1 683	1 683	S		0.5						1,2
Germacra-4(15),5,10(4)-trien-1- α-ol	1 687	1 685	S					0.4	0.4		1,2
α-Bisabolol	1 688	1 685	S		0.5						1,2
Eudesma-4(15),7-dien-1-β-ol	1 690	1 687	S	0.6					0.1		1,2
Eudesm-7(11)-en-4-ol	1 697	1 700	S			t	0.1				1,2
Heptadecane	1 700	1 700	A						0.2		1,2,3

TABLE 1 (Continued)

Compound[a]	RI[b]	Lit. RI[c]	Class[d]	Miramar		San Pedro		Pavas			Ident. method[e]
				Leaf	Flower	Leaf	Branch	Leaf	Flower	Branch	
Amorpha-4,9-dien -2-ol	1 699	1 700	S	t							1,2
10-Nor-Calamenen-10-one	1 701	1 702	B	t							1,2
Pentadecanal	1 724	1 717[j]	A		0.3		0.1		0.3		1,2
Isobicyclogermacrenal	1 730	1 733	S	t							1,2
Mint sulfide	1 738	1 740	S		0.5			0.6	0.4	0.1	1,2
2-α-Hydroxy-amorpha-4,7(11)-diene	1 775	1 775	S	t			0.3				1,2
Hexadecanal	1 836	1 836	A							0.1	1,2
6,10,14-Trimethyl-2-pentadecanone	1 848	1 848	IT		0.3						1,2
Farnesyl acetone	1 886	1 889	IT				t				1,2
Hexadecanoic acid	1 959	1 959	A				0.3				1,2,3
Ethyl hexadecanoate	1 992	1 993	A							0.1	1,2
(*Z*,*E*)-Geranyl linalool	1 998	1 997	D							0.2	1,2
(6*E*,10*Z*)-*pseudo* Phytol	2 016	2 018	D		0.2						1,2
(*Z*)-Phytol	2 014	2 014	D		0.1					0.2	1,2
(*E*)-Phytol	2 106	2 107	D					t			1,2
Linolenic acid	2 132	2 129	A							0.1	1,2
Docosane	2 200	2 200	A		t						1,2,3
Tricosane	2 300	2 300	A		t						1,2,3
Pentacosane	2 500	2 500	A		t						1,2,3
Hexacosane	2 600	2 600	A		t						1,2,3
Heptacosane	2 700	2 700	A		t						1,2,3
Octacosane	2 800	2 800	A		t						1,2,3
Nonacosane	2 900	2 900	A		t						1,2,3
Triacontane	3 000	3 000	A		t						1,2,3
Untriacontane	3 100	3 100	A		t						1,2,3
Total				97.3	95.6	96.0	98.6	93.1	93.4	96.8	
Compounds				121	129	92	93	102	84	90	

[a]Compounds listed in order of elution from 5 % phenyl/ 95 % dimethylpolysiloxane column. [b]RI = Retention index relative to C_8-C_{32} *n*-alkanes on the 5 % phenyl/95 % dimethylpolysiloxane column. [c]Lit. RI= (Adams, 2007). [d]Compound class: A, aliphatics; B, benzenoids; D, diterpenoids; IT, irregular terpenoids; M, monoterpenoids; Misc, miscellaneous; PP, phenylpropanoids; S, sesquiterpenoids. [e]Method: 1 = Retention index on 5 % phenyl/95 % dimethylpolysiloxane. 2 = MS spectra. 3 = Standard. [f](Jordan, Margaria, Shaw, & Goodner, 2002). [g](Radulovic, Dordevic, & Palic, 2010). [h](Ali et al., 2008). [i](Zoghbi et al., 1998). [j](Flamini et al., 2003).

t: traces (<0.05 %). Blank space = not detected. Asterisk* = compounds reported previously in Albuquerque et al. (2004) and Sobrinho et al. (2016). Bullet• = compounds reported in Rojas et al. (2008).

the percentages of the various classes of constituents of the essential oils are indicated. In total, 268 compounds were identified by means of GC-FID and GC-MS techniques, which represented 95.6 to 98.6 % of the total essential oil compositions.

Samples of the species were gathered in three different Costa Rican locations, showing qualitative similarities, but some major quantitative differences. The leaf essential oil obtained from Miramar was dominated by oxygenated sesquiterpenes (64.6 %), with caryophyllene oxide (22.5 %) (Fig. 1), viridiflorol (20.3 %) and spathulenol (8.3 %) as principal components, accompanied by lesser amounts in the 1.5-3.9 % range, namely α-pinene, β-caryophyllene, cubebol, humulene epoxide II, 1-*epi*-cubenol, δ-3-carene, *ar*-curcumene, *cis*-cadin-4-en-7-ol, β-pinene, and γ-curcumene. The main constituents of the leaf essential oil from San Pedro

TABLE 2
The chemical class distribution in the essential oils of *Baccharis trinervis* from three locations in Costa Rica

Compound class	Miramar				San Pedro				Pavas					
	Leaf %	NC	Flower %	NC	Leaf %	NC	Branch %	NC	Leaf %	NC	Flower %	NC	Branch %	NC
Aliphatics (A)	t	9	0.9	28	0.2	7	0.6	9	0.4	9	0.9	9	0.5	11
Alcohols			t	2	0.2	2			02	2	0.1	1	0.1	2
Aldehydes	t	5	0.6	10	t	3	0.3	8	0.1	3	0.5	3	0.2	4
Ketones	t	1	t	2					t	1				
Acids							0.3	1					0.1	1
Esters	t	1	0.1	2		1			0.1	3			0.1	3
Hydrocarbons	t	2	0.2	12		1					0.3	5	t	1
Terpenoids	97.0	106	94.5	96	95.8	83	97.8	80	92.7	91	92.3	72	94.9	77
***Monoterpenoids* (M)**	15.3	51	7.3	41	20.7	34	10.4	24	27.8	38	5.6	27	27.8	25
Monoterpene hydrocarbons	10.8	21	5.5	19	20.1	19	10.1	13	24.7	19	4.8	16	26.7	17
Oxygenated monoterpenes	4.5	30	1.8	22	0.6	15	0.3	11	3.1	19	0.9	12	1.1	8
***Sesquiterpenoids* (S)**	81.7	55	86.6	52	75.1	48	87.4	55	64.9	52	86.6	45	67.1	50
Sesquiterpene hydrocarbons	17.1	32	63.4	34	64.3	32	72.3	35	30.7	34	47.4	30	46.9	30
Oxygenated sesquiterpenes	64.6	23	22.7	17	10.8	16	15.1	20	33.6	17	38.8	14	20.1	19
Sulfur sesquiterpenes			0.5	1					0.6	1	0.4	1	0.1	1
***Diterpenoids* (D)**			0.3	2					t	1			0.4	2
Irregular terpenoids (IT)			0.3	1			t	1						
Aromatics	0.3	5	0.1	2	t	3	t	2					t	1
Benzenoids (B)	0.1	4	0.1	2	t	2	t	2	t	1			t	1
Phenylpropanoids (PP)	0.2	1			t	1					0.2	1		
Miscellaneus (Misc)	t	1	0.1	3			0.2	2	t	1	t	1	1.0	1
TOTAL	97.3	121	95.6	129	96.0	92	98.6	93	93.1	102	93.4	84	96.8	90

NC: number of compounds. t: traces (<0.05 %).

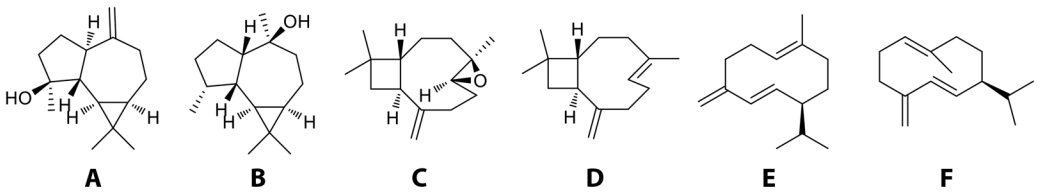

Fig. 1. Chemical structures of some principal sesquiterpenic constituents of *Baccharis trinervis* essential oil from Costa Rica: a) Spathulenol, b) viridiflorol, c) caryophyllene oxide, d) β-caryophyllene, e) germacrene D, and f) germacrene B.

were germacrene D (19.1 %), germacrene B (16.0 %), β-caryophyllene (9.1 %), viridiflorol (8.8 %), and δ-3-carene (6.8 %). Other significant constituents in the 1.3-3.4 % range were δ-cadinene, α-pinene, β-elemene, γ-elemene, β-phellandrene, α-thujene, and β-pinene. The main components of Pavas leaf essential oil were viridiflorol (21.0 %), β-caryophyllene (7.9 %), δ-3-carene (6.6 %), germacrene D (6.3 %), and α-pinene (5.9 %). These compounds were accompanied by other significant constituents in the 1.4-3.0 % range, namely β-elemene, spathulenol, limonene, β-pinene, bicyclogermacrene, α-cadinol, caryophyllene oxide, α-thujene, sabinene, γ-muurolene, δ-cadinene, and germacrene B.

The composition of the flower essential oil obtained from samples collected in the localities of Miramar and Pavas were dominated by sesquiterpenoids (86.6 %) with *cis*-muurola-4(14),5-diene (13.7 %), β-caryophyllene (9.5 %), bicyclogermacrene (8.3 %), and *ar*-curcumene (8.0 %) as major constituents, accompanied by lesser amounts of several compounds in the 2.2-4.7 % range, namely viridiflorol, germacrene D, germacrene B, spathulenol, *cis*-cadin-4-en-7-ol, γ-cadinene, β-elemene, and humulene or globulol (24.8 %), β-caryophyllene (17.1 %), germacrene D (9.9 %), bicyclogermacrene (5.9 %), spathulenol (4.8 %), caryophyllene oxide (4.7 %), and β-elemene (4.3 %). The branch essential oil from San Pedro sample also was constituted mainly by sesquiterpenoids (87.4 %) with germacrene B (18.7 %), germacrene D (14.7 %), β-caryophyllene (12.4 %) and globulol (11.3 %) as main constituents. There were also lesser amounts of several compounds in the 2.2-4.3 % range, namely δ-cadinene, bicyclogermacrene, β-copaene, β-elemene, and δ-3-carene. The branch essential oil from Pavas sample was constituted mainly by sesquiterpenoids (67.1 %) with more quantity of monoterpenoids (27.8 %) than the sample from San Pedro (10.4 %). The main compounds were germacrene D (15.6 %), viridiflorol (11.5 %), β-caryophyllene (10.1 %), δ-3-carene (8.1 %), β-phellandrene (6.5 %), bicyclogermacrene (4.9 %), and δ-cadinene (3.5 %).

As can be seen from table 1 and table 2, the major constituents of the leaf essential oil from the sample collected in Miramar were oxygenated sesquiterpenes (64.6 %), whereas sesquiterpene hydrocarbons (64.3 %) were the major components of the San Pedro sample. However, in the sample from Pavas, the two cited classes of metabolites were almost equally distributed (30.7 and 33.6 %, respectively).

DISCUSSION

The essential oil of fresh aerial parts of *Baccharis trinervis*, collected on Merouca mountain region of Ceará state, Northeastern Brazil (Albuquerque et al., 2004; Sobrinho et al., 2016), revealed that the major constituents were terpenoids with the presence of β-phellandrene (18.4-27.8 %), sabinene (10.9-14.2 %), α-thujene (6.6-10.5 %), (*Z*)-β-ocimene (2.3-8.1 %), α-pinene (5.5-8.7 %), and (*E*)-β-ocimene (1.9-6.3 %), including two non-terpenoid C-10 ene-diyne esters: methyl (*Z*)-dec-2-en-4,6-diynoate (0.8-14.6 %) and methyl (*E*)-dec-2-en-4,6-diynoate (10.7-14.7 %) not found in other oils of *Baccharis* species studied up to day. Rojas et al. (2008) examined

the essential oil from leaves collected on Santa Rosa, La Hechicera, in Mérida State (Venezuela). In this study, the authors reported that the major constituents were germacrene D (20.1 %), limonene (15.0 %), δ-cadinene (5.2 %), β-caryophyllene (4.8 %), α-pinene (4.5 %), and bicyclogermacrene (4.0 %), and this oil can be distinguished from the Brazilian ones in the fact that the main C-10 ene-diyne esters were absent. Our experimental data support those obtained by Rojas et al. (2008) because the results of the essential oil samples from the three different locations in Costa Rica do not contain those characteristic and very specific C-10 ene-diyne esters found in the Brazilian botanical material. As an additional support, the phytochemical study realized by Bohlmann and Zdero (1970) of fresh aerial parts of *B. trinervis*, cultured from seeds -of not specified origin- at Botanical Garden of the University of Berkeley, verified the presence of matricaria ester and three C-17 ene-diyne-diene esters but not C-10 ene-diyne esters (see also, Bohlmann, Burkhardt, & Zdero, 1973). Nonetheless, in a later phytochemical study of nine species of *Baccharis* collected in Brazil, the aerial parts of *B. trinervis* afforded, besides several terpenoids, one compound which has the trivial name lachnophyllum ester (probably, its *Z* isomer) corresponding to methyl dec-2-en-4,6-diynoate (Bohlmann et al., 1981). This was the first diacetylenic compound with established chemical constitution isolated from an essential oil (Sørensen, 1977). This significant variation in the qualitative composition of the essential oils of the same species collected in Venezuela and Costa Rica compared with the Brazilian samples could be caused by the habitat and environment factors as well as the genotype of the plant, but real sources of variability, according to Németh-Zámboriné (2016), are 'hard to determine'. Furthermore, it is known that *Baccharis* is a diverse and complex genus of the Asteraceae because some of the species present a high degree of morphological and chemical variability. One of the distinguishing factors of the oils from this plant growing wild in Costa Rica is the presence of an array of terpenoids with diverse carbon skeletons that could arise through various biosynthetic patterns. Especially important in number are the cadinane class and the guaiane family of sesquiterpenoids that are originated from the germacrane biosynthetic pathway. A distinctive character of the oils of *B. trinervis* studied from Costa Rica is the presence of the oxygenated sesquiterpenoids spathulenol, viridiflorol and globulol, in important amounts, accompanied by lesser quantities of several compounds of the same carbon skeleton, that are not found in the Venezuelan sample nor in the oils of Brazilian botanical material. These compounds also were found in *B. articulata* (Lam.) Pers. (Minteguiaga et al., 2015), *B. caprariifolia* DC. (Ferracini et al., 1995), *B. crispa* Spreng. (Simões-Pires et al., 2005), *B. dracunculifolia* DC. (Frizzo et al., 2008; Fabiane, Ferronatto, dos Santos, & Onofre, 2008), *B. erioclada* DC. (Ferracini et al., 1995), *B. platipoda* DC. (Ferracini et al., 1995; Quiroga, Ferracini, & Marsaioli, 1996), *B. semiserrata* DC. (Vannini et al., 2012), *B. tridentata* Vahl (Ferracini et al., 1995; Quiroga et al., 1996), *B. trimera* (Less.) DC. (Silva et al., 2007; Oliveira et al., 2012), *B. uncinella* (Fabiane et al., 2008), and *B. vincaefolia* Baker (Ferracini et al., 1995). Spathulenol appear to be a widespread compound in the essential oils from plants of the genus *Baccharis*. Our findings corroborate the presence of 41 compounds previously reported (Albuquerque et al., 2004; Sobrinho et al., 2016; Rojas et al., 2008) indicated by asterisks and bullets in table 1, whereas 227 constituents are newly reported in the composition of oils from *Baccharis trinervis*.

The aerial parts of *Baccharis trinervis* growing wild in Costa Rica produce terpenoid-rich essential oils whose compositions were dominated by either globulol (0-24.8 %), caryophyllene oxide (0.1-22.5 %), viridiflorol (0-21.0 %), germacrene D (0.5-19.1 %), germacrene B (0.2-18.7 %), β-caryophyllene (3.5-17.1 %), *cis*-muurola-4(14),5-diene (0-13.7 %), bicyclogermacrene (0-8.3 %), spathulenol (0.1-8.3 %), *ar*-curcumene (0-8.0 %), δ-3-carene (0.9-6.8 %), or α-pinene (0.3-5.9 %), according

to the morphological part studied or the locality of collection of the sample. The composition of the essential oils of *B. trinervis* from central Costa Rica is qualitatively different to the composition of the oils from samples of the same species collected in the state of Ceará, Brazil, which contain two characteristic stereoisomeric lachnophyllum esters, compounds not detected in this study. The essential oils of plants from Costa Rica resemble the composition of the oil from Venezuelan origin, but differ from both Brazilian and Venezuelan essential oils by the presence of sesquiterpenoids of the guaiane carbon skeleton, some of them as prominent members: viridiflorol, globulol, and spathulenol.

ACKNOWLEDGMENTS

The authors are grateful to Escuela de Química and Vicerrectoría de Investigación (UCR) for financial support (Project No. 809-B1-190) and to C. O. Morales (Biology School, UCR) for the species identification.

RESUMEN

Constituyentes de los aceites esenciales de *Baccharis trinervis* (Asteraceae) de Costa Rica. *Baccharis* (Asteraceae) es un género de plantas con flor que consta de 340 a 400 especies que habitan desde el sur de EE. UU. hasta Argentina y Chile, incluyendo América Central y varias islas del Caribe. *Baccharis trinervis* es un arbusto nativo de México, América Central y América del Sur. En Costa Rica, esta especie se conoce popularmente como *alcotán* y las hojas frescas se utilizan en forma de cataplasma para curar heridas y úlceras. El objetivo del presente estudio fue el de identificar los constituyentes químicos de los aceites esenciales obtenidos de diferentes partes morfológicas de *B. trinervis* en tres localidades de Costa Rica, obtenidos mediante el método de hidrodestilación. Se analizó la composición química de los aceites por cromatografía capilar de gases con detector de ionización de flama (GC-FID) y cromatografía de gases acoplada a un detector de masas (GC-MS), utilizando los índices de retención en una columna tipo DB-5 y los patrones de fragmentación, lo cual permitió la identificación de 268 constituyentes. Los siete aceites están constituidos principalmente por terpenoides (92.3 a 97.8 %). Los compuestos mayoritarios de los aceites de las hojas se identificaron como óxido de cariofileno (0.1-22.5 %), viridiflorol (8.8-21.0 %), germacreno D (0.5-19.1 %), germacreno B (0.2-16.0 %), β-cariofileno (3.5-9.1 %), espatulenol (0.1-8.3 %), δ-3-careno (2.0-6.8 %), α-pineno (2.5-5.9 %), biciclogermacreno (0-4.4 %), δ-cadineno (0.8-3.4 %), β-elemeno (0.8-3.0 %), limoneno (0.9-2.9 %) y β-pineno (1.3-2.5 %). Los aceites de las flores contienen principalmente globulol (0-24 %), β-cariofileno (9.5-17.1 %), *cis*-muurola-4(14),5-dieno (t-13.7 %), germacreno D (4.3-9.9 %), biciclogermacreno (5.9-8.3 %), *ar*-curcumeno (0-8.0 %), espatulenol (4.3-4.8 %), óxido de cariofileno (3.1-4.7 %), viridiflorol (0.3-4.7 %), β-elemeno (2.5-4.3 %), germacreno B (1.8-4.3 %), γ-cadineno (0.3-2.5 %), δ-3-careno (0.9-2.2 %) y α-humuleno (1.8-2.2 %). Los constituyentes mayoritarios del aceite de las ramitas fueron: germacreno B (1.4-18.7 %), germacreno D (14.7-15.6 %), β-cariofileno (10.1-12.4 %), viridiflorol (0-11.5 %), globulol (0.6-11.3 %), δ-3-careno (4.1-8.1 %), β-felandreno (1.5-6.5 %), biciclogermacreno (3.6-4.9 %), δ-cadineno (3.5-4.3 %), β-copaeno (0.6-2.8 %), β-elemeno (1.3-2.7 %) y γ- muuroleno (1.6-2.6 %). Los aceites estudiados presentan una composición compleja y se diferencian de los aceites obtenidos de la misma especie que crece en Brasil por la ausencia de los compuestos isoméricos diacetilénicos dec-2-en-4,6-diinoato de metilo (*Z* y *E*). También se diferencian de los aceites de las plantas de Brasil y Venezuela por la presencia de sesquiterpenoides de la familia de los guayanos, en especial por cantidades apreciables de viridiflorol, globulol y espatulenol.

Palabras clave: *Baccharis trinervis*, Asteraceae, aceites esenciales, terpenoides, GC-MS, Costa Rica.

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