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Article

# **Essential Oil Composition of Stems and Fruits of** *Caralluma europaea* **N.E.Br.** (Apocynaceae)

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**Abstract:** The essential oil of the stems and fruits of *Caralluma europaea* (Guss.) N.E.Br. (Apocynaceae) from Lampedusa Island has been obtained by hydrodistillation and its composition analyzed. The analyses allowed the identification and quantification of 74 volatile compounds, of which 16 were aromatic and 58 non-aromatic. Stems and fruits contained 1.4% and 2.7% of aromatic compounds respectively, while non-aromatic were 88.3% and 88.8%. Non-aromatic hydrocarbons were the most abundant compounds in both organs, followed by fatty acids. Data showed differences in the profiles between stems and fruits which shared only eighteen compounds; stems accounted for 38 compounds with twelve versus four in stems. Among the volatiles identified in stems and fruits of *C. europaea* 26 are present in other taxa of Apocynaceae, 52 are semiochemicals for many insects, and 21 have antimicrobial activity. The possible ecological role of the volatiles found is briefly discussed.

**Keywords:** antimicrobial; Apocynaceae; *Caralluma europaea*; essential oils; semiochemicals

## 1. Introduction

Volatile compounds with different ecological roles are widely produced by plants. The review by Dudereva et al. [1] indicates the different roles, such as pollinator attraction, defence from phytophagous and pathogenic microbes, allelopathy, seed dispersal, and thermotolerance, among others. There are few studies on the chemical composition of the genus Caralluma. The presence of pregnane steroids in several species of *Caralluma* has been reported in previous chemical studies [2–5] and it could indicate a systematical importance within the genus. On the other hand only a few species have shown the occurrence of flavonoids [6-8] and the only paper published on the chemical constituents of Caralluma europaea (Guss.) N.E.Br. is that of Meve and Heneidak [9]. Recently Formisano et al. [10] analysed the chemical volatiles composition by headspace of C. europaea and discussed their possible role in the biology of pollination linked to the sapromyiophilous syndrome typical of the Stapeliads. Caralluma europaea [= Apteranthes europaea (Guss.) Plowes] is a stemsucculent member of Apocynaceae - Asclepiadoideae, distributed in Egypt, S. Spain, Italy (Lampedusa Island), Libya, Tunisia, Algeria and Morocco [9]. It has quadrangular stems and forms large clumps up to 15–20 cm in diameter, flowers are red-brown with yellow stripes or strikes, 10–15 mm in diameter, and the corona is normally purplish [11]. Fruits are dehiscent follicles up to 20 cm long which at maturity release wind-dispersed seeds. To the best of our knowledge, no phytochemical studies on the essential oil of any species of Caralluma have been reported so far. In the present paper we present data on the essential oil composition of stems and fruits of C. europaea by hydrodistillation and compare the results with data available in scientific literature.

#### 2. Results and Discussion

The analysis by GM/MS allowed the identification of 74 volatile compounds of which 16 aromatic and 58 non-aromatic (Table 1). Stems (S) and fruits (F) contained 1.4% and 2.7% of aromatic compounds respectively, while non-aromatic were 88.3% and 88.8%.

K <sub>i1</sub> <sup>a</sup>	$K_{i2}^{b}$	Ident. <sup>c</sup>	Compounds	S %	F %
800	800	1, 2, 3	Octane	0.3	
901		1, 2	Heptanal		t
936	1075	1, 2, 3	α-Pinene		0.4
963	1543	1, 2, 3	Benzaldehyde		0.3
980	1454	1, 2	1-Octen-3-ol		0.6
1001		1, 2	Octanal		0.1
1002		1, 2	2-Pentylfuran		0.1
1044	1663	1, 2, 3	Phenylacetaldehyde		0.6

**Table 1.** Percent composition of the essential oils of stems (S) and fruits (F) of *Caralluma europaea* (Guss) N.E.Br.

105816571, 2, 3Acctophenone1110971, 2Nonanl0.111021, 2Nonanl111071, 24-Ebtyl benzatdehyde111071, 23Safrand0.211071, 2Safrand0.20.212061, 2Decanal0.40.412081, 20-Conene0.7t12121, 20-Conene0.7t12131, 20-Cyclocitral0.11.212141, 21, 2, 3, 4-tetrahydro-1, 5, 7-trimethylnaphthalene0.6t121924711, 2, 3Indole0.61.213061, 21, 2, 3, 4-tetrahydro-1, 5, 7-trimethylnaphthalene0.60.6131321801, 2Undecanal0.60.613421, 21, 2, 3/Entrahydro-1, 1, 6-trimethylnaphthalene0.60.613421, 21, 2-Dihydro-1, 1, 6-trimethylnaphthalene0.20.313421, 20, 2-Dohegee0.21.213541, 2						
10971.2Methyl benzoate1.00.111021.2Nonanal1111031.24.Ethyl benzaldehyde1111731.2.3Naphtalene1111791.2Safranal10.211091.2Ocanal0.40.412081.20.Conene0.1112121.20.Conene0.1112131.21.2.3.4tetrahydro-1.5.7-trimethylnaphthalene1112141.21.2.3.4tetrahydro-1.5.7-trimethylnaphthalene1112151.2.31.dole0.110.113161.2Undecanal001131321801.2Undecanal0013421.21.2-Dihydro-1.1.6-trimethylnaphthalene00.213431.20.2-Didydro-ar-ionene00.213441.20.2-Didydro-ar-ionene00.213451.22.Erhyl-1.4-dimethylenprene00.213461.22.Erhyl-1.4-dimethylenprene00.213471.22.Erhyl-1.4-dimethylenprene0014101.22.Erhyl-1.4-dimethylenprene1014101.22.Erhyl-1.4-dimethylenprene1014101.22.Erhyl-1.4-dimethylenprene1114101.22.Erhyl-1.4-dimethylenprene1114101.22.Erhyl-1.4-dimethylenprene<	1058	1657	1, 2, 3	Acetophenone		t
1102         1,2         Nonanal         r         t           1167         1734         1,2         4-Entyl benzaldehyde	1097		1, 2	Methyl benzoate		0.1
1167         1734         1.2         4-Ethyl benzaldehyde         1           1179         1763         1.2.3         Naphtalene         t           1197         1.2.3         Safranal         0.2           1206         1508         1.2         Decanal         0.4           1208         1.2 $0$ -conene         0.7         t           1212         1.2 $\beta$ -Cyclocitral         0.1         t           1214         1.2 $1.2.3$ , <i>b</i> -Cyclocitral         0.3         0.3           1221         2471         1.2.3         Indea         0.6         0.3           1306         1.2         Undecanal         0.6         0.1         1.3           1313         2180         1.2         Undecanal         0.6         0.2           1334         1.2         Undecanal         0.6         0.2           1349         1.2         Delydro-1,1.6-trimethylnaphthalene         0.6         0.2           1358         1787         1.2         (D-1-Durdro-1)         0.2         0.3           1349         1.2         Delydro-arionene         0.2         1.5           1450         1.2         Schylotene <td>1102</td> <td></td> <td>1, 2</td> <td>Nonanal</td> <td></td> <td>t</td>	1102		1, 2	Nonanal		t
117917631.2.3Naphtalenet111971.2Safranal0.20.212061.2.0Cacanal0.40.412081.20lonene0.7t12121.2J.2.0β-Cyclocitral0.7t12141.21.2.3J-Cyclocitral1.00.712151.21.2.3J-Cyclocitral1.01.012161.21.2.3J-Cyclocitral0.01.012161.2.11.2.3Indole0.10.1131321801.2Undecanal0.10.113141.2.2Undecanal0.10.113151.2.3I-Cyclophyro-1.1.6-trimethylnaphthalene0.20.113491.21.2.12-Dihydro-1.1.6-trimethylnaphthalene0.20.213491.21.2.2Dehydro-ar-ionene0.10.313811.31.2.4Cyclophene1.00.214091.21.2.2Dehydro-ar-ionene0.20.214151.2.1D-Cubehene1.00.214161.21.2V-Cubehene1.00.214171.21.2Dedecanal0.10.315201.2Dedecanal1.01.11.114501.21.2Ordecanal1.01.515411.2Ordecanal1.01.51.515512.51.2Dedecanal1.0	1167	1734	1, 2	4-Ethyl benzaldehyde		
1197	1179	1763	1, 2, 3	Naphtalene	t	
1206         158         1,2         Decanal         0.4           1208         1,2 $\alpha$ -lonene         0.7         t           1212         1,2 $\beta$ -Cyclociral         0.1         0.1           1213         1,2 $\beta$ -Cyclociral         0.1         0.1           1243         1,2 $1,2,3,4$ -tetrahydro-1,5,7-trimethylnaphthalene         0.6         1           1261         1,2         ( <i>B</i> )-2-Decenal         0.6         1         0.1           1306         1,2         Undecanal         0.6         1         0.1           1313         2180         1,2         Undycon-1,16-trimethylnaphthalene         0.5         0.5           1342         1,2         1,2-Dihydro-1,1.6-trimethylnaphthalene         0.5         0.5           1342         1,2         Dehydro-ar-ionene         0.4         0.2           1358         1787         1,2         Dehydro-ar-ionene         0.5         0.5           1440         1,2         Methyl indole         t         t         0.7           1410         1,2         Methyl indole         t         1.2         1.2           1410         1,2         Spathulenol         1.	1197		1, 2	Safranal		0.2
1208         1,2         α-Ionene         0,7         t           1212         1,2         β-Cycloirtal         0.1           1243         1,2         1,2,3,4-tetrahydro-1,5,7-trimethylnaphthalene         7         t           1261         1,2         ( <i>β</i> )-2-Decenal         0.3         0.3           1291         2471         1,2,3         Indole         0.6         7           1306         1,2         Undecanal         0.4         0.1           1313         2180         1,2         Undecanal         0.4         0.4           1342         1,2         Dehydro-ar-ionene         0.5         0.3           1388         1787         1,2         Dehydro-ar-ionene         0.2         1.4           1409         1,2         2-Ethyl-1,4-dimethylbenzene         0.2         1.4         0.3           1388         1787         1,2         Dodecanal         1.4         0.2           1410         1,2         S-Ethyl-1,4-dimethylbenzene         4.9         1.2           1410         1,2         Widrene         4.9         1.2           1450         1621         1,2         Widrene         1.2         1.5	1206	1508	1, 2	Decanal		0.4
1212I.2β-CyclocinalI.00.11243I.2I.2,3,4-tetrahydro-1,5,7-trimethylnaphthaleneII1261I.2I.2,3,4-tetrahydro-1,5,7-trimethylnaphthaleneI.00.312912471I.2,3Indole0.31306I.2UndecanalI.00.113132180I.2I.2UndecanalI.01314I.2I.2I.2-Dihydro-1,1,6-trimethylnaphthaleneI.00.31342I.2I.2Dehydro-ar-ioneneI.00.31343I.2J.2Dehydro-ar-ioneneI.00.31382I.2J.2Dehydro-ar-ioneneI.00.31382I.2J.2Dehydro-ar-ioneneI.00.31382I.2J.2Dehydro-ar-ioneneI.00.31409I.22-Ethyl-1,4-dimethylbenzeneI.00.31410I.2J.2Dehydro-ar-ioneneI.00.31410I.2ValerenolI.00.31513152I.2Methyl indoleI.11414I.2SynthalenolI.2I.215782150I.2SynthalenolI.215782150I.2SpathalenolI.215782150I.2SpathalenolI.21574I.2PentadecanolI.41582151I.2.3TetradecanolI.41792I.2I-OctadecanolI.41794I.	1208		1, 2	α-Ionene	0.7	t
12431, 21,2,3,4-tetrahydro-1,5,7-trimethylnaphthalene1t12611, 2 $(E)$ -2-Decenal0.3129124711, 2, 3Indole0.613061, 2Undecanal0.6131321801, 24-Vinylguaiacol0.413421, 21,2-Dihydro-1,1,6-trimethylnaphthalene0.413431, 21,2-Dihydro-1,1,6-trimethylnaphthalene0.413441, 2Dehydro-ar-ionene0.413451, 2 $\beta$ -Cubebene1.414091, 22-Ethyl-1,4-dimethylbenzene1.614101, 2Methyl indolet14111, 2Methyl indolet141517221, 2Dodecanal14101, 2Sp-Cuplenxadiene-1,4-dione, 2,6-bis(1,1-dimethyltehyltehyl)0.3150917461, 22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethyltehyltehyl)0.3150917461, 2Spathulenol1.2157821501, 2Spathulenol1.2165122531, 2Spathulenol1.216542131, 2Feradecanol0.417711, 2Peradecanol0.4178821311, 2Valerenol0.7184521311, 2Hexadydrofarnesylacetone3.818921, 2I-Octadecene0.4190019001, 2, 3Nonadecane0.419011, 2I-Nonadecene0.6 <td>1212</td> <td></td> <td>1, 2</td> <td>β-Cyclocitral</td> <td></td> <td>0.1</td>	1212		1, 2	β-Cyclocitral		0.1
1261         1,2         (E)-2-Decenal         0.3           1291         2471         1,2,3         Indole         0.6           1306         1,2         Undecanal         0.1           1313         2180         1,2         Variagenal         0.1           1313         2180         1,2         Variagenal         0.4           1342         1,2         1,2-Dihydro-1,1.6-trimethylnaphthalene         0.2           1348         1,2         Dehydro-ar-ionene         0.2           1358         1787         1,2         (E)-β-Damascenone         0.2           1409         1,2         2-Ethyl-1,4-dimethylbenzene         1.2         0.2           1410         1,2         Dedecanal         r         0.2           1410         1,2         Dedecanal         r         0.2           1410         1,2         Dodecanal         r         0.2           1410         1,2         Vidrene         4.9         0.3           1509         1621         1,2         Widrene         1.2         1.2           151         1,2         Spathulenol         1.2         1.5         1.5           1651         253	1243		1, 2	1,2,3,4-tetrahydro-1,5,7-trimethylnaphthalene		t
129124711,2,3Indole0.613061,2Undecanal0.1131321801,2Undecanal0.1131421801,21,2-Dihydro-1,1,6-trimethylnaphthalene0.513491,2Dehydro-ar-ionene0.5138817871,2(£)-B-Damascenone0.313821.2S-Cubebene1.20.214001,2Acthyl indolet0.214101,2Nethyl indolet0.214101,2Octecanal0.20.3145016211,2Notecanal0.214101,2S-S-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.3145016211,2Spathulenol1.214701,2(2)-α-Bisabolene1.21.2157821501,2Spathulenol1.2157821531,2Spathulenol1.216741,2Valerenol1.21.216741,2Valerenol1.21.217711,2Petradecanol0.41.217821511,2Iteradecanol0.617921,2Iteradecanol0.41.218931,2Iteradecanol0.41.219941,2Iteradecanol0.41.219951,2Nonadecane0.41.219951,2Steadecanoi caid ethyl ester0.61.21994	1261		1, 2	(E)-2-Decenal		0.3
13061.2UndecanalI.00.11131321801.24-Vinylguaiacol0.40.413421.21.2-Dihydro-1.1,6-trimethylnaphthalene1.00.513491.21.2Dehydro-ar-ionene1.00.2135817871.2 <i>(E)</i> -Damascenone1.00.213821.2 <i>B</i> -Cubebene1.00.214091.22-Ethyl-1.4-dimethylbenzene1.00.214101.2Jocacanal1.00.2141117221.2Dodecanal0.2141517221.2Methyl indole1.00.314161.2J.2S-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.314101.22.5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.30.3150917461.2(Z)-α-Bisabolene1.21.2157821501.2Spathulenol1.21.2165122531.2Spathulenol1.21.216541.2Valerenol1.21.2165521331.2Valerenol1.21.217711.21.2Valerenol3.82.317822131.2.3Tetradecanol3.82.317921.21-Octadecene0.41.7184521311.2.3Hexadecanol3.82.317921.21-Storadecene0.41.718452131 <td>1291</td> <td>2471</td> <td>1, 2, 3</td> <td>Indole</td> <td>0.6</td> <td></td>	1291	2471	1, 2, 3	Indole	0.6	
131321801,24-Vinylguaicol10.40.4.413421.41,2.01,2-Dihydro-1,1,6-trimethylnaphthalene10.40.513491.2Dehydro-ar-ionene10.40.2135817871,2(£)-β-Damascenone10.40.313821.2β-Cubebene1.40.31.414091.2β-Cubebene1.41.21.214101.2B-Cubehene1.40.31.4141517221.2Dodecanal0.71.414151724J.2Dodecanal0.71.414151724J.2Dodecanal0.30.314151724J.2Systeman1.21.214161.2Videre4.91.21.314171.41.2Systeman1.11.314181211.2Systeman1.21.515391.4J.2Systeman1.21.516591.2J.2Valerenol1.21.216741.2Valerenol1.21.216741.3J.2Valerenol1.21.217731.31.2Valerenol1.41.217842.131.2Valerenol1.41.217931.3Hexadecanal1.41.717941.3Hexadecanal1.41.717951.4J.2Valerenol1.4	1306		1, 2	Undecanal		0.1
13421,21,2-Dihydro-1,1,6-trimethylnaphthalene0.513491,2Dehydro-ar-ionene0.2135817871,20.313821,20.313821,20.313821,20.214091,20.214101,20.2141517221,2Dodecanal0.7145016211,2Widdrene4.90.314701,2Systembere.1,4-dione, 2,6-bis(1,1-dimethylethyl)0.3150917461,21.5165122531,2Spathulenol1.216591,2Valerenol1.216591,2Valerenol0.4175821311,2,3Tetradecanol caid0.717641,2Pentadecanol0.7175821311,2Nonadecene0.617641,2Pentadecanol0.7175821311,2Nonadecene0.617591,2Nonadecene	1313	2180	1, 2	4-Vinylguaiacol		0.4
13491, 2Dehydro-ar-ionene0.2135817871, 2(E)-β-Damascenone0.313821, 2β-Cubebene114091, 22-Ethyl-1,4-dimethylbenzene0.214101, 2S-Cubebene0.214101, 2Methyl indolet141517221, 2Dodecanal0.7145016211, 2Viddrene4.914701, 22, 5-Cyclohexadiene-1, 4-dione, 2, 6-bis(1, 1-dimethylethyl)0.3150917461, 2(Z) α-Bisabolene1.2157821501, 2Spathulenol1.2165122531, 2Spathulenol1.2165422531, 2Valerenol1.2165422531, 2Valerenol1.2177111, 2Pentadecanol caid0.4178821311, 2Hexadecanal0.7184521311, 2Hexadecanal0.7184521311, 2Hexadecanoi caid ethyl ester0.4190019001, 2, 3Hexadecanoi caid ethyl ester0.6195526221, 2i. Cosane0.61956293	1342		1, 2	1,2-Dihydro-1,1,6-trimethylnaphthalene		0.5
135817871,2(E)-β-Damascenone0.313821.2β-Cubebene1114091.2β-Cubebene0.214101.22-Ethyl-1,4-dimethylbenzene10.214101.2Methyl indolet0.7141517221,2Dodecanal0.7145016211,2Widdrene4.90.714701,22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.3150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.95.4165122531,2β-Eudesmol1.95.416541,2Valernol1.21.95.4165827131,2,3Tetradecanoic acid0.41.2177141,2Pentadecanoic acid5.61.717821311,2I-Octadecene0.61.7184521311,2Hexadecanoic acid3.82.818921,21-Nonadecene0.41.719051,2,3Hexadecanoic acid ethyl ester0.61.719571,2,3Hexadecanoic acid7.89.619921,2,3Hexadecanoic acid ethyl ester0.61.719571,2,3Hexadecanoic acid ethyl ester0.61.7195823111,2I-Eicosane0.61.719571,2,3Hexadecanoic acid ethyl ester <td< td=""><td>1349</td><td></td><td>1, 2</td><td>Dehydro-ar-ionene</td><td></td><td>0.2</td></td<>	1349		1, 2	Dehydro-ar-ionene		0.2
1382.1.2β-Cubebene.1.14091.22-Ehyl-1,4-dimethylbenzene0.214101.23.2Methyl indolet14151.7221.2Dodecanal0.7145016211.2Viddrene4.914701.22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.3150917461.2(Z)-α-Bisabolene1.2157821501.2Spathulenol1.2157821501.2Spathulenol1.2165122531.2β-Eudesmol1.216741.2Valerenol1.216741.2Tetradecanolic acid0.4175827131.2,3Tetradecanolic acid0.4175827131.2,2Pentadecanolic acid0.617711.21-Octadecene0.60.7184521311.2Hexadocanal0.419001.2,3Nonadecane0.82.819221.21.2I-Nonadecene0.619351.2I-Nonadecanic acid ethyl ester0.419571.2,3Hexadocanoic acid ethyl ester0.6195823111.2,3Hexadocanoic acid ethyl ester0.6195823121.2,3Hexadocanoic acid ethyl ester0.6195823541.2,3Hexadocanoic acid ethyl ester0.6195926221.20.50.5195926231.2,3Eicosane	1358	1787	1, 2	( <i>E</i> )- β-Damascenone		0.3
1409.12.2Ethyl-1,4-dimethylbenzene.0.214101,2Methyl indolet14151,221,2Dodecanal0.7145016211,2Viddrene4.914701,22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)150917461,22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.5165122531,2β-Eudesmol1.216741,2Valerenol1.216741,2Tetradecanolic acid0.4175827131,2,3Tetradecanolic acid0.417711,2Pentadecanolic acid0.617711,2Pentadecanolic acid0.6178921311,2Hexadecanal0.7184521311,2Hexadecanal0.4190019001,2,3Nonadecane0.8195026221,2(Z)-Phytol1.719571,2,3Hexadecanolic acid ethyl ester0.6199320311,2,3Hexadecanolic acid ethyl ester0.619951,2,3Hexadecanolic acid ethyl ester0.619951,23.53.619951,23.53.619951,23.53.6	1382		1, 2	β-Cubebene		t
1410141517221,2Dodecanal0.7145016211,2Vidrene4.914701,22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.5165122531,2β-Eudesmol1.216591,2Valerenol1.216741,2Tetradecanol0.4175827131,2,3Tetradecanol0.417711,2Pentadecanol0.6178121351,21-Octadecene0.6181921351,2Hexadecanal0.7184521311,21-Nonadecene0.4190019001,2,3Nonadecane0.819571,2,3Hexadecanol caid ethyl ester0.6195829311,2,3Hexadecanoi caid ethyl ester0.619591,2,3Hexadecanoi caid0.7195829311,2,3Hexadecanoi caid ethyl ester0.619591,2J-Eicosene0.6195020001,2,3Eicosane0.919511,2J-Eicosene0.6 <t< td=""><td>1409</td><td></td><td>1, 2</td><td>2-Ethyl-1,4-dimethylbenzene</td><td></td><td>0.2</td></t<>	1409		1, 2	2-Ethyl-1,4-dimethylbenzene		0.2
141517221,2Dodecanal1.00.7145016211,2Widdrene4.91.214701.22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.3150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.2165122531,2Spathulenol1.95.416591.2Valerenol1.21.216741.2Valerenol1.21.2167527131,2,3Tetradecanol caid0.41.217714.1,2Pentadecanol caid0.61.2178121351,21-Octadecene0.61.218921.21-Octadecene0.41.20.7184521311,2Hexadycofarnesylacetone3.82.8190019001,2,3Nonadecene0.41.71957 $\Lambda$ 1,2,3Hexadecanoi caid ethyl ester0.61.7195829311,2,3Hexadecanoi caid ethyl ester0.61.71959 $\Lambda$ 1,2,3Hexadecanoi caid ethyl ester0.61.7195829311,2,3Eicosane0.91.2200020001,2,3Eicosane0.91.1200120001,2,3Hexadecanoi caid1.11.1200225971,2Octadecanoi0.61.1200325971,2Octadecanoi2.5	1410		1, 2	Methyl indole	t	
145016211,2Widrene4.914701,22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)0.3150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.95.4165122531,2β-Eudesmol1.21.916541,2Valerenol1.21.216741,2Tetradecanoi caid0.41.2167527131,2,3Tetradecanoi caid5.617711,2Pentadecanoi caid0.60.6178921351,2Hexadecanal0.617921,21-Octadecene0.60.6181921351,2Hexadecanal0.7184521311,2Hexadydofarnesylacetone3.82.8190019001,2,3Nonadecane0.81.719571,2,3Hexadecanoi caid ethyl ester0.60.7195829311,2,3Hexadecanoi caid ethyl ester0.619001,2,3Hexadecanoi caid ethyl ester0.60.7195829311,2,3Hexadecanoi caid7.89.619921,2,3Eicosane0.91.11.1200323541,2Octadecanal1.11.120141,2,3Heneicosane2.53.22.59720101,2,3Hexadecanoi caid ethyl ester0.61.120101,2,3Hexadecanoi caid1.1	1415	1722	1, 2	Dodecanal		0.7
1470.1,22,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl).0.3150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.5165122531,2β-Eudesmol1.95.41659.1,2Valerenol1.21.21674.1,2Tetradecanol0.41.2175827131,2,3Tetradecanol0.41.21771.1,2Pentadecanol5.61.20.31792.1,21-Octadecene0.60.61.2181921351,2Hexadecanal0.70.7184521311,21-Octadecene0.41.2190019001,2,3Nonadecane0.82.81957.1,21-Nonadecene0.61.7195829311,2,3Hexadecanoic acid ethyl ester0.60.7195829311,2,3Hexadecanoic acid ethyl ester0.60.61992.1,21-Eicosene0.61.71.7195829311,2,3Eicosane0.91.2200020001,2,3Eicosane0.91.1202323541,2Octadecanol1.11.1202425971,2Octadecanol0.73.2210021001,2,3Heneicosane2.53.221001001,2,3Heneicosane0.41.1	1450	1621	1, 2	Widdrene	4.9	
150917461,2(Z)-α-Bisabolene1.2157821501,2Spathulenol1.5165122531,2 $\beta$ -Eudesmol1.95.416591,2Valerenol1.21.216741,2Valerenol0.41.2167527131,2,3Tetradecanolc acid5.617711,2Pentadecanol0.617921,21-Octadecene0.6181921351,2Hexadecanal0.7184521311,2Hexadecanal0.4190019001,2,3Nonadecene0.8195026221,2(Z)-Phytol1.719571,2,3Hexadecanoic acid ethyl ester0.6195829311,2,3Hexadecanoic acid ethyl ester0.6195829311,2,3Hexadecanoic acid ethyl ester0.6195020001,2,3Eicosane0.919221,21-Eicosene0.6200020001,2,3Eicosane0.9201021001,2Octadecanal1.1202323541,2Octadecanal0.1203021001,2,3Heneicosane2.53.2210021001,2,3Heneicosane2.53.2	1470		1, 2	2,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)		0.3
157821501,2Spathulenol1.5165122531,2β-Eudesmol1.95.416591,2Valerenol1.21.216741,2Tetradecanol0.41.2175827131,2,3Tetradecanol5.61.217711,21,2Pentadecanol0.60.317921,21.2Pentadecanol0.60.6181921351,2Hexadecanal0.70.7184521311,2Hexadecanal0.42.818921,21-Octadecene0.42.8190019001,2,3Nonadecane0.82.8195026221,2(Z)-Phytol1.70.7195829311,2,3Hexadecanoic acid ethyl ester0.60.619921,2,3Hexadecanoic acid ethyl ester0.60.619921,2,3Iccosane0.61.17200020001,2,3Eicosane0.91.11202323541,2Octadecanol0.120.2210021001,2,3Henciosane2.53.2210021001,2,3Henciosane0.40.4	1509	1746	1, 2	(Z)-α-Bisabolene	1.2	
16512253 $1, 2$ $\beta$ -Eudesmol $1.9$ $5.4$ 1659 $1, 2$ Valerenol $1.2$ $1.2$ 1674 $1, 2$ Tetradecanol $0.4$ $1.2$ 17582713 $1, 2, 3$ Tetradecanolc acid $5.6$ 1771 $1, 2$ Pentadecanol $0.6$ $0.3$ 1792 $1, 2$ 1-Octadecene $0.6$ $0.6$ 18192135 $1, 2$ Hexadecanal $0.7$ 18452131 $1, 2$ Hexahydrofarnesylacetone $3.8$ $2.8$ 1892 $1, 2$ 1-Nonadecene $0.4$ $0.4$ 19001900 $1, 2, 3$ Nonadecane $0.8$ $0.7$ 19502622 $1, 2$ (Z)-Phytol $1.7$ $0.7$ 19532931 $1, 2, 3$ Hexadecanoic acid ethyl ester $0.6$ $0.7$ 19582931 $1, 2, 3$ Hexadecanoic acid $7.8$ $9.6$ 1992 $1, 2$ $1$ -Eicosene $0.6$ $0.9$ $0.9$ 20232354 $1, 2$ Octadecanal $1.1$ $0.2$ 2100 $1, 2, 3$ Heneicosane $0.4$ $0.4$	1578	2150	1, 2	Spathulenol		1.5
16591,2Valerenol1.21.2 $1674$ 1,2Tetradecanol0.40.4 $1758$ $2713$ $1,2,3$ Tetradecanolc acid5.6 $1771$ 1,2Pentadecanol0.3 $1792$ 1,21-Octadecene0.6 $1819$ $2135$ $1,2$ Hexadecanal0.7 $1845$ $2131$ $1,2$ Hexadecanal0.7 $1845$ $2131$ $1,2$ Hexadydrofarnesylacetone $3.8$ $2.8$ $1892$ $1,2$ 1-Nonadecene0.41 $1900$ $1900$ $1,2,3$ Nonadecane0.81 $1950$ $2622$ $1,2$ (Z)-Phytol $1.7$ 0.7 $1958$ $2931$ $1,2,3$ Hexadecanoic acid ethyl ester0.60.6 $1992$ $1,2,3$ Hexadecanoic acid $7.8$ $9.6$ $1992$ $1,2,3$ Eicosane0.91 $2000$ $2000$ $1,2,3$ Eicosane0.9 $2023$ $2354$ $1,2$ Octadecanal $1.1$ $2082$ $2597$ $1,2$ Heneicosane $2.5$ $3.2$ $2100$ $2100$ $1,2,3$ Heneicosane $2.5$ $3.2$	1651	2253	1, 2	β-Eudesmol	1.9	5.4
16741, 2Tetradecanol0.41 $1758$ $2713$ $1, 2, 3$ Tetradecanoic acid $5.6$ 0.3 $1771$ 1, 2Pentadecanol0.30.3 $1792$ 1, 21-Octadecene0.60.6 $1819$ $2135$ $1, 2$ Hexadecanal0.7 $1845$ $2131$ $1, 2$ Hexahydrofarnesylacetone $3.8$ $2.8$ $1892$ 1, 21-Nonadecene0.40.4 $1900$ $1, 2, 3$ Nonadecane0.81 $1950$ $2622$ $1, 2$ (Z)-Phytol1.71.7 $1957$ 1, 2, 3Hexadecanoic acid ethyl ester0.60.7 $1958$ $2931$ $1, 2, 3$ Hexadecanoic acid ethyl ester0.60.7 $1958$ $2931$ $1, 2, 3$ Hexadecanoic acid7.89.6 $1992$ 1, 21-Eicosene0.61.11.1 $2023$ $2354$ $1, 2$ Octadecanal1.11.1 $2082$ $2597$ $1, 2$ Octadecanol0.20.2 $2100$ $1, 2, 3$ Heneicosane2.53.2 $2102$ $1, 2$ $1, 2$ $2$ -Nonadecanone0.4	1659		1, 2	Valerenol	1.2	
1758         2713         1, 2, 3         Tetradecanoic acid         5.6           1771         1, 2         Pentadecanol         0.3           1792         1, 2         1-Octadecene         0.6           1819         2135         1, 2         Hexadecanal         0.7           1845         2131         1, 2         Hexadecanal         0.4           1900         1900         1, 2, 3         Nonadecene         0.4           1950         2622         1, 2         (Z)-Phytol         1.7         1.7           1957         1, 2, 3         Hexadecanoic acid ethyl ester         0.6         1.7           1958         2931         1, 2, 3         Hexadecanoic acid         0.9         1.1           2000         2000         1, 2, 3         Eicosane <t< td=""><td>1674</td><td></td><td>1, 2</td><td>Tetradecanol</td><td>0.4</td><td></td></t<>	1674		1, 2	Tetradecanol	0.4	
1771         1,2         Pentadecanol         0.3           1792         1,2         1-Octadecene         0.6           1819         2135         1,2         Hexadecanal         0.7           1845         2131         1,2         Hexadecanal         0.4           1900         1900         1,2,3         Nonadecene         0.4         1           1900         1900         1,2,3         Nonadecane         0.8         1.7           1957         1,2,3         Hexadecanoic acid ethyl ester         0.7         0.7           1958         2931         1,2,3         Hexadecanoic acid         7.8         9.6           1992         1,2         1-Eicosene         0.6         1         1           2000         2000         1,2,3         Eicosane         0.2         1.1         1           2082         2597         1	1758	2713	1, 2, 3	Tetradecanoic acid	5.6	
1792         1, 2         1-Octadecene         0.6           1819         2135         1, 2         Hexadecanal         0.7           1845         2131         1, 2         Hexahydrofarnesylacetone         3.8         2.8           1892         1, 2         1-Nonadecene         0.4         1.1           1900         1900         1, 2, 3         Nonadecane         0.8         1.1           1900         1900         1, 2, 3         Nonadecane         0.8         1.1           1950         2622         1, 2         (Z)-Phytol         1.7         1.7           1957         1, 2, 3         Hexadecanoic acid ethyl ester         0.6         0.7           1958         2931         1, 2, 3         Hexadecanoic acid         7.8         9.6           1992         1, 2         1-Eicosene         0.6         1.1         1.1           2000         2000         1, 2, 3         Eicosane         0.9         1.2           2023         2354         1, 2         Octadecanol         1.1         1.1           2082         2597         1, 2         Octadecanol         2.5         3.2           2100         2100         1, 2, 3	1771		1, 2	Pentadecanol		0.3
1819         2135         1, 2         Hexadecanal         0.7           1845         2131         1, 2         Hexahydrofarnesylacetone         3.8         2.8           1892          1, 2         1-Nonadecene         0.4            1900         1900         1, 2, 3         Nonadecane         0.8            1950         2622         1, 2         (Z)-Phytol         1.7          0.7           1957          1, 2, 3         Hexadecanoic acid ethyl ester          0.7           1957          1, 2, 3         Hexadecanoic acid ethyl ester          0.7           1958         2931         1, 2, 3         Hexadecanoic acid         7.8         9.6           1992          1, 2         1-Eicosene         0.6            2000         2000         1, 2, 3         Eicosane         0.9            2023         2354         1, 2         Octadecanol          0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102          1, 2         2-Nonadecanone	1792		1, 2	1-Octadecene	0.6	
1845         2131         1, 2         Hexahydrofarnesylacetone         3.8         2.8           1892         1, 2         1-Nonadecene         0.4         0.4           1900         1900         1, 2, 3         Nonadecane         0.8         1.7           1950         2622         1, 2         (Z)-Phytol         1.7         1.7           1957         1, 2, 3         Hexadecanoic acid ethyl ester         0.7         0,7           1958         2931         1, 2, 3         Hexadecanoic acid ethyl ester         0.6         0.7           1958         2931         1, 2, 3         Hexadecanoic acid ethyl ester         0.6         0.7           1958         2931         1, 2, 3         Hexadecanoic acid         0.9         0.6           1992         1, 2         1-Eicosene         0.6         1.1         1.1           2000         2000         1, 2, 3         Eicosane         0.9         1.1           2082         2597         1, 2         Octadecanol         0.2         0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4         1.4	1819	2135	1, 2	Hexadecanal		0.7
1892         1, 2         1-Nonadecene         0.4           1900         1900         1, 2, 3         Nonadecane         0.8           1950         2622         1, 2         (Z)-Phytol         1.7           1957         1, 2, 3         Hexadecanoic acid ethyl ester         0,7           1958         2931         1, 2, 3         Hexadecanoic acid ethyl ester         0,6           1992         1, 2         1-Eicosene         0.6            2000         2000         1, 2, 3         Eicosane         0.9           2023         2354         1, 2         Octadecanoi         1.1           2082         2597         1, 2         Octadecanoi         0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4	1845	2131	1, 2	Hexahydrofarnesylacetone	3.8	2.8
1900         1900         1, 2, 3         Nonadecane         0.8           1950         2622         1, 2         (Z)-Phytol         1.7           1957         1, 2, 3         Hexadecanoic acid ethyl ester         0,7           1958         2931         1, 2, 3         Hexadecanoic acid         7.8         9.6           1992         1, 2         1-Eicosene         0.6             2000         2000         1, 2, 3         Eicosane         0.9            2000         2000         1, 2, 3         Eicosane         0.9            2023         2354         1, 2         Octadecanol         1.1            2082         2597         1, 2         Octadecanol         0.2          0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4	1892		1, 2	1-Nonadecene	0.4	
1950       2622       1, 2       (Z)-Phytol       1.7         1957       1, 2, 3       Hexadecanoic acid ethyl ester       0,7         1958       2931       1, 2, 3       Hexadecanoic acid ethyl ester       7.8       9.6         1958       2931       1, 2, 3       Hexadecanoic acid       7.8       9.6         1992       1, 2       1-Eicosene       0.6       0.6         2000       2000       1, 2, 3       Eicosane       0.9         2023       2354       1, 2       Octadecanal       1.1         2082       2597       1, 2       Octadecanol       0.2         2100       2100       1, 2, 3       Heneicosane       2.5       3.2         2102       1, 2       2-Nonadecanone       0.4       0.4	1900	1900	1, 2, 3	Nonadecane	0.8	
1957         1, 2, 3         Hexadecanoic acid ethyl ester         0,7           1958         2931         1, 2, 3         Hexadecanoic acid         7.8         9.6           1992         1, 2         1-Eicosene         0.6         1.2           2000         2000         1, 2, 3         Eicosane         0.9         1.1           2023         2354         1, 2         Octadecanal         1.1         1.1           2082         2597         1, 2         Octadecanol         0.2         0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4         1.4	1950	2622	1, 2	(Z)-Phytol	1.7	
1958       2931       1, 2, 3       Hexadecanoic acid       7.8       9.6         1992       1, 2       1-Eicosene       0.6       1.2         2000       2000       1, 2, 3       Eicosane       0.9       1.1         2023       2354       1, 2       Octadecanal       1.1       1.1         2082       2597       1, 2       Octadecanol       0.2       0.2         2100       2100       1, 2, 3       Heneicosane       2.5       3.2         2102       1, 2       2-Nonadecanone       0.4       1.4	1957		1, 2, 3	Hexadecanoic acid ethyl ester		0,7
1992         1, 2         1-Eicosene         0.6           2000         2000         1, 2, 3         Eicosane         0.9           2023         2354         1, 2         Octadecanal         1.1           2082         2597         1, 2         Octadecanol         0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4         14	1958	2931	1, 2, 3	Hexadecanoic acid	7.8	9.6
2000         2000         1, 2, 3         Eicosane         0.9           2023         2354         1, 2         Octadecanal         1.1           2082         2597         1, 2         Octadecanol         0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4         1.4	1992		1, 2	1-Eicosene	0.6	
2023       2354       1, 2       Octadecanal       1.1         2082       2597       1, 2       Octadecanol       0.2         2100       2100       1, 2, 3       Heneicosane       2.5       3.2         2102       1, 2       2-Nonadecanone       0.4	2000	2000	1, 2, 3	Eicosane	0.9	
2082         2597         1, 2         Octadecanol         0.2           2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4         0.4	2023	2354	1, 2	Octadecanal	1.1	
2100         2100         1, 2, 3         Heneicosane         2.5         3.2           2102         1, 2         2-Nonadecanone         0.4         0.4	2082	2597	1, 2	Octadecanol		0.2
2102 1, 2 2-Nonadecanone 0.4	2100	2100	1, 2, 3	Heneicosane	2.5	3.2
	2102		1, 2	2-Nonadecanone	0.4	

Table 1. Cont.

2104	3160	1, 2, 3	(Z,Z)-9,12-Octadecadienoic acid	5.2	2.4
2132	2625	1, 2	(E)-Phytol	2.6	3.9
2194		1, 2	1-Docosene	0.2	
2200	2200	1, 2, 3	Docosane	0.4	1.4
2300	2300	1, 2, 3	Tricosane	4.4	7.3
2400	2400	1, 2, 3	Tetracosane	1.7	1.9
2452		1, 2	Docosanol	0.4	
2493		1, 2	1-Pentacosene	2.1	
2500	2500	1, 2, 3	Pentacosane	5.4	6.5
2594		1, 2	1-Hexacosene		2.1
2600	2600	1, 2	Hexacosane		2.9
2630		1, 2	Tetracosanal		0.9
2658		1, 2	1-Tetracosanol		0.4
2700	2700	1, 2	Heptacosane	6.1	9.9
2728		1, 2	Hexacosanal		1.9
2793		1, 2	1-Octacosene		1.8
2800	2800	1, 2	Octacosane	2.4	0.8
2827		1, 2	Squalene	1.2	1.2
2900	2900	1, 2	Nonacosane	8.3	6.5
3100	3100	1, 2	Hentriacontane	9.5	7.7
3200	3200	1, 2	Dotriacontane	0.9	0.3
3300	3300	1, 2	Tritriacontane	1.4	1.4
			Total compounds	89.7	91.5

Table 1. Cont.

<sup>a</sup>  $K_{i1}$ : HP 5MS column; <sup>b</sup>  $K_{i2}$ : HP Innowax column; <sup>c</sup> Ident.: 1 = retention index identical to bibliography; 2 = identification based on comparison of MS; 3 = retention time identical to authentic compounds; t: trace amount < 0.05%.

Non-aromatic hydrocarbons were the most abundant compounds in both organs, followed by fatty acids. The most abundant compounds were hentriacontane (S 9.5%; F 7.7%) nonacosane (S 8.3%; F 6.5%), heptacosane (6.1%; 9.9% F), tricosane (S 4.4%; F 7.3%), pentacosane (S 5.4%; F 6.5%) hexadecanoic acid (S 7.8%; F 9.6%),  $\beta$ -eudesmol (S 1.9%; F 5.4%), tetradecanoic acid (S 5.6%; F 0%) and (*Z*,*Z*)-9,12-octadecadienoic acid (S 5.2%; F 2.4%). Data showed differences in the profiles between stems and fruits which shared only eighteen compounds; stems accounted for 38 compounds while fruits for 53. Fruits showed a higher diversity especially in aromatic compounds with 12 compounds versus four in stems. Among the scarce literature available on volatiles in aerial parts of Apocynaceae, excluding flowers, some compounds have been found in leaves and stems of *Catharanthus roseus* [12,13] and in fruits of *Hancornia speciosa* [14] (Table 2).

Fifty-five volatiles found in stems and fruits of *C. europaea* are semiochemicals for many insects (Table 2). There are no synomones, which are usually related to pollinators and common in the flowers, while there are 28 attractants, 32 allomones, 21 pheromones and 49 kairomones. In literature there are several papers devoted to the highly specialized role of plant-animal interactions [1] and the semiochemicals present in *C. europaea* may play key roles in the adaptation of the species to its environment.

Table 2.	Essential	oils	of the	stems	and	fruits	of	Caralluma	europaea	(Guss)	N.E.Br.
arranged	by class.										

Compounds		emio	chei	mica	als <sup>a</sup>	۸	Anonimono				
Compounds	Α	Al	P	K	Sy	Antimicrobiai	Apocynaceae				
Aromatic Compounds											
Aldehydes											
Benzaldehyde	x	х	x	х			LC [12, 13]				
							SC [13]				
Phenylacetaldehyde	х	х	х	х			FH [14]				
							LC [13]				
							SC [13]				
4-Ethylbenzaldehyde						Х					
Hydrocarbons											
Naphtalene	х		х	х							
α-Ionene											
1,2,3,4-tetrahydro-1,5,7-trimethylnaphthalene											
1,2-Dihydro-1,1,6-trimethylnaphthalene											
Dehydro-ar-ionene											
2-Ethyl-1,4-dimethylbenzene											
Esters											
Methyl benzoate	х		х	х		Х	FH [14]				
Oxygen containing compounds							-				
2-Pentylfuran											
Ketones											
Acetophenone	х	х	х	Х		Х					
2,5-Cyclohexadiene-1,4-dione,2,6-bis(1,1-											
dimethyl-ethyl)											
Phenolic compounds				-							
4-Vinylguaiacol						Х					
Nitrogen containing compounds											
Indole	x	х	x	х		Х	LC [13]				
Methyl indole											
Non	-Aro	matic	e Coi	npot	inds						
Hydrocarbons											
Octane	x			х							
1-Octadecene		х		х							
1-Nonadecene		х		х							
Nonadecane	x	х		х			LC [12]				
1-Eicosene				х							
Eicosane			x	х			LC [12]				
Heneicosane	х			х							
1-Docosene				х							
Docosane		х	x	х			LC [12]				
Tricosane	х	х	х	X			LC [12]				

 Table 2. Cont.

Tetracosane	х	Х	Х	Х		LC [12]
1-Pentacosene				X		
Pentacosane	х	х	х	х		
1-Hexacosene				X		
Hexacosane	х	Х		х		
Heptacosane		х		X		
1-Octacosene		Х				
Octacosane		х		х		
Nonacosane	х	х		x		
Hentriacontane				х		
Dotriacontane				X		
Tritriacontane				x		
Alcohols						
1-Octen-3-ol	х	Х	X	х		FH [14]
Tetradecanol	х			х	х	
Pentadecanol				х	х	
Octadecanol				Х		FH [14]
Docosanol				х		
1-Tetracosanol						
Aldehydes		-				
Heptanal	х	х	х	х		
Octanal	х	х	х	х	Х	LC [13]
Negeral						SC [13]
Nonanai	X	Х	X	X	X	EU [12]
Decanal	v	v	v	v	v	I [ [14]
Decanar	л	Λ	Λ	Λ	~	EC [12] FH [14]
(E)-2-Decenal	X	x	x	x		LC [12, 13]
						SC [13]
						FH [14]
Undecanal	х	х		X	х	LC [12]
Dodecanal		х	x	х		LC [12]
Hexadecanal	X	х		X	х	FH [14]
Octadecanal				х	х	
Tetracosanal						
Hexacosanal						
Ketones						
$(E)$ - $\alpha$ -Damascenone						
Hexahydrofarnesylacetone				X		LC [13]
						SC [13]
2-Nonadecanone						
Monoterpene Hydrocarbons					1	1
α-Pinene	х	х	х	х	Х	

Oxygenated Monoterpenes							
Safranal							LC [13]
α-Cyclocitral							LC [13]
Sesquiterpene hydrocarbons							
β-Cubebene							
Widdrene							
(Z)-α-Bisabolene							
Oxygenated sesquiterpenes							
Spathulenol	Х					Х	
β-Eudesmol		х					
Valerenol							
Fatty acids					-		
Tetradecanoic acid		Х		х		Х	LC [12]
Hexadecanoic acid	х	х	Х	х		Х	LC [12]
(Z,Z)-9,12-Octadecadienoic acid	Х	Х	Х	х		Х	LC [12]
Esters							
Hexadecanoic acid ethyl ester				х			LC [13]
							SC [13]
Diterpenes							
(Z)-Phytol						Х	LC [13]
(E)-Phytol		Х		х		Х	
Triterpenes							
Squalene	х	х		х		Х	

Table 2. Cont.

<sup>a</sup> Semiochemicals: (A: Attractant; Al: Allomone; K: Kairomone; P: Pheromone; Sy: Synomone) [15]. <sup>b</sup> Antimicrobial:

Antimicrobial Data of Drugs, Natural Compounds and Essential Oils [16]. <sup>c</sup> Aerial parts of other Apocynaceae: LC:

Leaves of Catharanthus roseus [12,13]; SC: Stems of Catharanthus roseus [13]; FH: Fruits of Hancornia speciosa [14].

Plant semiochemicals are known to produce a wide range of behavioral responses in insects. Some insects sequester or acquire host plant compounds and use them as sex pheromones or sex pheromones precursors. Other insects produce or release sex pheromones in response to specific host plant cues, and chemicals from host plants often synergistically enhance the response of an insect to sex pheromones [17]. It is interesting to note that at least four of the most abundant volatiles found in *C. europaea* (pentacosane, hexacosane, heptacosane and hexadecanoic acid) are male pheromones for *Danaus chrysippus* [18], a butterfly whose larvae feed on plants rich in cardenolides like Apocynaceae and Moraceae [19]. In a recent paper Pisciotta *et al.* [20] observed that *D. chrysippus* in Lampedusa island oviposited only on the fruits of *C. europaea* (Figure 1) and that larvae fed on its fruits and stems (Figure 2).

**Figure 1.** Egg of *Danaus chrysippus* on a fruit of *C. europaea* in Lampedusa Island (Photo by P. Zito).



Figure 2. Larvae of *D. chrysippus* feeding on fruits of *C. europaea* in Lampedusa Island (Photo by P. Zito).



According to Reddy and Guerrero [17] the effects of host plants on pheromone behavior appear to be part of male strategies to maximize encounters with females as well as of female strategies to gain access to new feeding and oviposition sites. It is possible that the male pheromones guide the female of *D. chrysippus* to the ovipostion site and influences the feeding behavior of the larvae, thus having a negative effect on the fitness of the plant. Twenty one volatiles found in *C. europaea* are antimicrobial

agents (Table 2) and fatty acids are among the main constituents. (Z,Z)-9,12-Octadecadienoic acid, tetradecanoic acid and hexadecanoic acid show antimicrobial activity against *Candida albicans*, *Clostridium welchii* and *Staphylococcus aureus* [21,22]. Walters *at al.* [23] also indicated that (Z,Z)-9,12-octadecadienoic acid has antifungal activities on the plant pathogenic fungi: *Rhizoctonia solani*, *Pythium ultimum*, *Pyrenophora avenae* and *Crinipellis perniciosa*. According to González-Lamothe *et al.* [24] plants are continuously in contact with different microorganisms, including viruses, bacteria and fungi many of which are pathogens that affect plant development, reproduction and ultimately yield production.

## 3. Experimental

Plant material was collected in Lampedusa Island (Italy,  $35^{\circ}29'28''$  and  $35^{\circ}21'39'' N - 12^{\circ}30'54''$  and  $12^{\circ}37'55'' E$ ) from plants growing in the "Isola dei Conigli" area at an altitude of 100 m a.s.l. Stems and fruits were collected in April 2008, placed in paper bags and kept at  $4 \pm 1$  °C for three hours before the hydrodistillation. Clones of the plants used are cultivated at the Botanical Garden of Palermo and a voucher specimen (N° PAL/MS/1112) was deposited in the Herbarium, Orto Botanico, Palermo, Italy.

Air dried stems (23.64 g) and fruits (41.67 g) were hand-cut into small fragments and hydrodistilled in a Clevenger-type apparatus for three hours as previously described by Riela et al. [25]. The waxy oils were collected by *n*-pentane extraction, dried over anhydrous sodium sulphate and removal of the solvent. The essential oil yields was 0.38 mg (1.60%) and 4.90 mg (11.75%) for stems and fruits, respectively. The oil samples, characterized by a typical malodorous odour, were stored in a refrigerator at -10 °C until analysed. Analyses of essential oils were performed on a Perkin Elmer Sigma 115 gas chromatograph (GC) equipped with two different polarity-fused silica capillary columns: HP 5MS and HP Innowax, both 30 m long x 0.25 mm ID; 0.25 µm film thickness. Temperature program: initial temperature, 40 °C; hold 5 min; temperature rate 4 °C min<sup>-1</sup>, final temperature 250 °C; hold 30 min; column flow rate 1.0 mL He min<sup>-1</sup>; injector and detector temperatures 260 °C and 280 °C, respectively. Injection volume: 1.0 µL of diluted samples (1/100 v/v, in *n*-pentane) in the splitless mode. GC/MS analyses were performed on a Agilent 6850 Series II apparatus using an HP-5 fused silica capillary column (30 m long  $\times$  0.25 mm ID; 0.33 µm film thickness), connected to a quadrupole detector operating in electron impact (EI) mode at 70 eV; electron multiplier energy 2,000 V. Most constituents were identified by gas chromatography by comparison of their retention indices  $(R_i)$  with either those of the literature [26,27] or with those of authentic compounds available in our laboratories. The retention indices were determined in relation to a homologous series of *n*-alkanes ( $C_8$ - $C_{28}$ ) under the same operating conditions. All the compounds were identified by comparison of their mass spectra on both columns with either those stored in NIST 02 and Wiley 275 libraries or with mass spectra from the literature [26,28] and a home made library. Component relative concentrations were calculated based on GC peak areas without using correction factors. Pure commercial essential oil components used as standards for GC-FID analyses were obtained from Aldrich and Fluka.

## 4. Conclusions

Among the volatile compounds found in *C. europaea* several have semiochemical and antimicrobial activities. As regards to semiochemicals they may play a role in the defence of the plant against herbivores by discouraging foraging on stems and fruits [1]. It is interesting to note that, as reported by Dudareva *et al.* [1], some volatiles may not always be beneficial to the plant. This is the case of the four pheromones which attract *Danaus chrysippus* to oviposit on fruits and to feed on stems and fruits. These pheromones play a role as kayromones at least in these combination of species: *C. europaea* – *D. chrysippus*. The presence of antimicrobials could increase the fitness of the plant by arresting the spread of pathogens. Further investigations on *C. europaea* essential oils would be interesting to test the actual antimicrobial potential and to verify also its pharmaceutical interest.

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#### **References and Notes**

- 1. Dudareva, N.; Negre, F.; Nagegowda, D.A.; Orlova, I. Plant Volatiles: Recent Advances and Future Perspectives. *Crit. Rev. Plant Sci.* **2006**, *25*, 417–440.
- 2. Suresh, B.K.; Rama, S.R.; Vyasa, R.S.; Madhusudana, R.J.; Siva, R.S. A new pregnane steroid from the stems of *Caralluma umbellata*. J. Asian Nat. Prod. Res. **2008**, 10, 1013–1016.
- Abdel-Sattar, E.; Harraz, F.M.; Al-Ansari, S.M.A.; El-Mekkawy, S.; Ichino, C.; Kiyohara H.; Ishiyama, A.; Otoguro, K.; Omura, S.; Yamada, H. Acylated pregnane glycosides from *Caralluma tuberculata* and their antiparasitic activity. *Phytochemistry* 2008, 69, 2180–2186.
- Kunert, O.; Rao, V.G.; Babu, G.S.; Sujatha, P.; Sivigamy, M.; Anuradha, S.; Rao, B.V.; Kumar, B.R.; Alex, R.M.; Schuhly, K.; Kuhnelt, D.; Rao, G.V.; Rao, A.V. Pregnane glycosides from *Caralluma adscendens* var. *fimbriata. Chem. Biodiv.* 2008, *5*, 239–250.
- 5. Abdel-Sattar, E.; Ahmed, A.A.; Hegazy, M.E.F.; Farag, M.A.; Al-Yahya, M.A.A. Acylated pregnane glycosides from *Caralluma russelliana*. *Phytochemistry* **2007**, *68*, 1459–1463.
- 6. Bader, A.; Braca, A.; De Tommasi, N.; Morelli, I. Further constituents from *Caralluma* negevensis. *Phytochemistry* **2003**, *62*, 1277–1281.
- Kamil, M.; Jayaraj, A.F.; Ahmad, F.; Gunasekhar, C.; Samuel, S.; Chan, K.; Habibullah M.; Attas, A. Separation of flavonoids from *Caralluma arabica* using high-speed counter-current chromatography. *J. Pharm. Pharmacol.* 2000, *52*, 265.
- Ramesh, M.; Rao, Y.N.; Kumar, M.R.; Mohan G.K.; Kumar, B.R.; Roa, A.V.N.A.; Krishna, M.R.; Reddy, B.M. Flavone glycoside from three *Caralluma* species. *Biochem. Syst. Ecol.* 1999, 27, 85–86.
- 9. Meve, U.; Heneidak, S. A morphological, karyological and chemical study of the *Apteranthes* (*Caralluma*) *europaea* complex. *Biol. J. Linnean Soc.* **2005**, *149*, 419–432.

- Formisano, C.; Senatore, F.; Della Porta, G.; Scognamiglio, M.; Bruno, M.; Maggio, A.; Rosselli, S.; Zito, P.; Sajeva, M. Headspace Volatile Composition of the Flowers of *Caralluma europaea* N.E. Br. (Apocynaceae). *Molecules* 2009, *14*, 4597–4613.
- 11. Sajeva, M.; Costanzo, M. Succulents—The Illustrated Dictionary; Cassel plc: London, UK, 1994; pp. 58–59.
- Pandey-Rai, S.; Mallavarapu, G.R.; Naqvi, A.A.; Yadav, A.; Kumar, R.S.; Srivastava, S.; Singh, D.; Mishra, R.; Kumar, S. Volatile components of Leaves and Flowers of Periwinkle *Catharanthus roseus* (L.) G. Don from New Delhi. *Flavour Fragr. J.* 2006, *21*, 427–430.
- De Pinho, P.G.; Gonçalves, R.S.; Valentão, P.; Pereira, D.M.; Seabra, R.M.; Andrade, P.B.; Sottomayor, M. Volatile Composition of *Catharanthus roseus* (L.) G. Don using Solid Phase Microextraction and Gas Chromatography\Mass Spectrometry. *J. Pharm. Biomed. Anal.* 2009, 49, 674–685.
- 14. Sampaio, T.S.; Nogueira, P.C.L. Volatile Components of Mangaba Fruit (*Hancornia speciosa* Gomes) at Three Stages of Maturity. *Food Chem.* **2006**, *95*, 606–610.
- 15. El-Sayed, A.M. *The Pherobase: Database of Insect Pheromones and Semiochemicals.* http://www.pherobase.com/, accessed on 28 December 2009.
- 16. Pauli, A. Amicbase-Databases: Collections of Antimicrobial Data of Drugs, Natural Compounds and Essential Oils. www.reviewscience.com/, accessed on 28 December 2009.
- 17. Reddy, G.V.P.; Guerrero, A. Interactions of insect pheromones and plant semiochemicals. *Trends Plant Sci.* **2004**, *9*, 253–261.
- 18. Schulz, S.; Boppré, M.; Vane-Wright, R.I. Specific mixture of secretions from male scent organs of African milkweed butterflies (Danainae). *Phil. Trans. R. Soc. Lond. B.* **1993**, *342*, 161–181.
- 19. Ackery, R.I.; Vane-Wrigth, R.I. *Milkweed Butterflies, Their Cladistics and Biology*; British Museum (Natural History): London, UK, 1984; pp. 80–92.
- Pisciotta, S.; Zito, P.; Sajeva, M. *Danaus Chrysippus* (Linnaeus, 1758) (Lepidoptera Nymphalidae) Larvae Feeding on *Caralluma europaea* (Guss.) N.E. Br. (Asclepiadaceae) in Lampedusa Island. *Nauralista sicil.* 2008, 32, 241–251.
- Bodoprost, J.; Rosemeyer, H. Analysis of Phenacylester Derivatives of Fatty Acids from Human Skin Surface Sebum by Reversed-Phase HPLC: Chromatograpic Mobility as a Function of Physico-Chemical Properties. *Int. J. Mol. Sci.* 2007, *8*, 1111–1124.
- 22. Cañas-Rodriguez, A.; Smith, H.W. The Identification of the Antimicrobial Factors of the Stomach Contents of Sucking Rabbits. *Biochem. J.* **1966**, *100*, 79–82.
- 23. Walters, D.; Raynor, L.; Mitchell, A.; Walker, R.; Walker, K. Antifungal activities of four fatty acids against Plant Pathogenic fungi. *Mycopathologia* **2004**, *157*, 87–90.
- González-Lamothe, R.; Mitchell, G.; Gattuso, M.; Diarra, M.S.; Malonin, F.; Bourab, K. Plant Antimicrobial Agents and their effects on Plant and Human Pathogenes. *Int. J. Mol. Sci.* 2009, 10, 3400–3419.
- Riela, S.; Bruno, M.; Formisano, C.; Rigano, D.; Rosselli, S.; Saladino, M.L.; Senatore, F. Studies on the effects of solvent free microwave extraction on the chemical composition of essential oil of *Calamintha nepeta* (L.) Savi compared with conventional method. *J. Sep. Sci.* 2008, *31*, 1110–1117.

- 26. Jennings, W.; Shibamoto, T. *Qualitative Analysis of Flavor and Fragrance Volatiles by Glass Capillary Chromatography*; Academic Press: New York, NY, USA, 1980.
- 27. Davies, N.W. Gas Cromatographyc detection indexes of monoterpenes and sesquiterpenes on methyl silicone and Carbowax 20 M phases. J. Chromatogr. A. **1990**, 503, 1–24.
- 28. Adams, R.P. Identification of Essential Oils Components by Gas Chromatography/Mass Spectrometry, 4th ed.; Allured Publ. Corp.: Carol Stream, IL, USA, 2007.

Sample Availability: Samples of the compounds are available from the authors.

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