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# American Journal of Essential Oils and Natural Products

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 American  
Journal of  
Essential  
Oils and  
Natural  
Products

ISSN: 2321-9114  
 AJEONP 2018; 6(2): 01-06  
 © 2018 AkiNik Publications  
 Received: 01-02-2018  
 Accepted: 05-03-2018

## Carlos Chaverri

School of Chemistry and Natural  
 Products Research Center  
 (CIPRONA), University of Costa  
 Rica. San Jose, 11501-2060 Costa  
 Rica

## Jose F Ciccio

School of Chemistry and Natural  
 Products Research Center  
 (CIPRONA), University of Costa  
 Rica. San Jose, 11501-2060 Costa  
 Rica

## Essential oils from *Eucalyptus deglupta* (Myrtaceae) cultivated in Costa Rica

Carlos Chaverri and Jose F Ciccio

### Abstract

*Eucalyptus* is a Myrtaceous genus of flowering plants of about 700-800 species, mostly native to Australia. The aim of this work was to study the chemical composition of the essential oils from the leaves, twigs and fruits of *Eucalyptus deglupta* cultivated in Costa Rica. The essential oils were obtained by hydrodistillation and the chemical composition of the oils was analyzed by capillary gas chromatography with a flame detector (GC-FID) and gas chromatography-mass spectrometry (GC-MS) using the retention indices (RI) on a DB-5 type capillary column. A total of 146 compounds were identified, accounting for 94.1-96.0% of the total amount of the oils. The major constituents in the leaf oil were  $\alpha$ -phellandrene (32.7%),  $\alpha$ -pinene (16.8%), *p*-cymene (12.6%), limonene (5.2%),  $\beta$ -phellandrene (5.0%), (*E*)-nerolidol (4.4%), and  $\beta$ -pinene (4.0%). The twig oil consisted mainly of  $\alpha$ -pinene (37.8%), *p*-cymene (19.6%), and  $\beta$ -pinene (6.3%). The most significant constituents of the fruit oil were  $\alpha$ -phellandrene (20.4%), *p*-cymene (13.4%),  $\beta$ -pinene (8.9%),  $\beta$ -caryophyllene (5.1%), terpinolene (4.0%), and  $\alpha$ -terpinyl acetate (3.9%).

**Keywords:** *Eucalyptus deglupta*, Myrtaceae, essential oil composition,  $\alpha$ - and  $\beta$ -pinene,  $\alpha$ -phellandrene, *p*-cymene, Costa Rica

### 1. Introduction

Myrtaceae is a family of flowering plants with about 142 genera and *ca.* 5500 species<sup>[1]</sup> distributed over the world, occurring predominantly in tropical and southern temperate regions. This family comprises mainly trees and shrubs with mostly Southern Hemisphere distribution, with the majority of genera occurring in Australia and South America. One of the characteristics of this family is the presence of oil glands in the leaves that produce essential oils, mainly constituted by terpenoids. *Eucalyptus* O. Berg is a genus that contains about 700-800 species indigenous to the Australasian region<sup>[2]</sup>. *Eucalyptus deglupta* Blume (rainbow eucalyptus, Mindanao gum, kamarere)<sup>[3-5]</sup> is a large, fast-growing and evergreen tree of more than 30m tall (up to 60-75 m where it is native), with characteristic multi-colored smooth peeling bark with olive green, lime green, yellow, orange, bluish-gray, and purple-brown tones, somewhat with pendant branches. The leaves are broadly lanceolate, acuminate, simple, opposite or alternate, of about 15 cm long, with lighter green color below. Flowers are white to pale yellow with many stamens, disposed in axillary or terminal compound inflorescences (panicles of 3- to 7-flowered umbels). The fruits are pedicellate and with hemispheric (0.5 cm) capsular shape. It seems that this is the only species of *Eucalyptus* that is indigenous to the Northern Hemisphere; it is native to Philippines (Mindanao), Indonesia, and Papua New Guinea. This tree is cultivated in the wet tropics of the world, and planted in Costa Rica in humid lowlands and middle elevations (0-1800 m) with ornamental purposes due to its attractive bark, and used as shade tree by some coffee growers<sup>[6]</sup>. When the leaves and twigs are crushed they give off an aromatic scent. This species is used mainly as a source of timber for construction and furniture. The *Eucalyptus* leaf essential oils have been used in the treatment of lung diseases, as expectorant and cough stimulants, nasal decongestant and antiseptic<sup>[7, 8]</sup>. The leaf essential oils from *E. deglupta* growing in India<sup>[9]</sup>, Nigeria<sup>[10]</sup> and Democratic Republic of Congo<sup>[11]</sup> showed antibacterial and antifungal activities evaluated by the agar diffusion method. Also, essential oils from *Eucalyptus* have shown anti-influenza activity, especially for influenza virus type A infections<sup>[12]</sup>. Some phytochemical investigations have been performed on the species *E. deglupta* showing the occurrence of polyphenols<sup>[13]</sup>, terpenoids<sup>[14]</sup> and flavones<sup>[15]</sup>. Previous studies of the essential oil composition of the leaves of *E. deglupta*, growing in different regions of the world, reported

### Correspondence:

#### Jose F Ciccio

School of Chemistry and Natural  
 Products Research Center  
 (CIPRONA), University of Costa  
 Rica. San Jose, 11501-2060 Costa  
 Rica

the occurrence of terpenoids [11, 16-21] and the most significant constituents identified are summarized in Table 1. In general, mono- and sesquiterpenoids were the major constituents of the investigated oils. In this paper, the chemical composition

of the leaf, twig and fruit essential oils of *E. deglupta* cultivated in the Central Valley of Costa Rica was investigated. The leaf essential oil composition was compared to that previously reported in the literature.

**Table 1:** Main compounds present in several essential oils from *Eucalyptus deglupta*.

Collecting site	Plant part	Major constituents	References
New Guinea, Lae	Shade-dried leaves	( <i>E</i> )-Nerolidol (ca. 50.0%), $\alpha$ -pinene, $\alpha$ -phellandrene, <i>p</i> -cymene, ocimene, and 3-methylbutanal.	[16, 17]
Cuba, Topes de Collantes	Leaves	Nerolidol (66%).	[18] cited in [17]
Australia, Gadgarra, North Queensland	Leaves	$\alpha$ -Pinene, $\alpha$ -phellandrene and caryophyllene, with the absence of nerolidol.	[16]
Nigeria, Ibadan	Leaves	( <i>E</i> )-Nerolidol (34.8%), $\alpha$ -pinene (24.7%), and $\beta$ -caryophyllene (5.9%).	[19]
Democratic Republic of Congo, Kinshasa	Fresh leaves	1,8-Cineole (35.7%), cryptone (25.4%), myrtenol (7.4%), $\alpha$ -phellandrene (7.2%), and $\beta$ -terpineol (6.3%).	[11]
Republic of Côté d'Ivoire, Abidjan	Dried leaves	$\alpha$ -Phellandrene (42.3%), <i>p</i> -cymene (21.0%), and $\gamma$ -terpinene (8.1%).	[20]
Indonesia, Yogyakarta	Freshleaves	( <i>E</i> )-Nerolidol (31.6%), $\alpha$ -phellandrene (11.0%), benzene (?) (10.5%), aromadendrene (5.6%), and $\beta$ -caryophyllene (5.0%).	[21]

## 2. Materials and methods

### 2.1 Plant materials

The botanical material of *Eucalyptus deglupta* Blume was collected during the blooming and fruiting stage of the species in the locality of Río Segundo, Province of Alajuela (10°00'51"N, 84°11'40"W), Costa Rica, in July 2014, at an elevation of 960 m. A voucher specimen was deposited in the Herbarium of the University of Costa Rica (USJ 106770).

### 2.2 Isolation of the essential oils

The oil was collected by hydrodistillation in a modified Clevenger-type apparatus during 3 hours. The distilled oil was dried over anhydrous sodium sulfate (Na<sub>2</sub>SO<sub>4</sub>), filtered and stored between 0 °C and 10 °C in the dark, until further analysis. The essential oil yields (v/w) from diverse morphological parts were: 0.52% (fresh leaves), 0.07% (twigs) and 0.09% (fruits).

### 2.3 Gas chromatography (GC-FID)

The oils of *E. deglupta* were analyzed by gas chromatography with flame ionization detector (GC-FID) using a Shimadzu GC-2014 gas chromatograph. The data were obtained on a 5% phenyl-/95% dimethylpolysiloxane fused silica capillary column (30 m x 0.25 mm; film thickness 0.25  $\mu$ m), (MDN-5S, Supelco). The GC integrations were performed with a Shimadzu GCsolution™, version 2.3. The operating conditions used were: carrier gas N<sub>2</sub>, 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.

### 2.4 Gas chromatography-mass spectrometry (GC-MS)

The analysis by gas chromatography coupled to mass selective detector (GC-MS) was carried out using a Shimadzu GC-17A gas chromatograph coupled with a GCMS-QP5000 apparatus and Shimadzu GC MS solution™ software, version 1.21, with Wiley 139 and NIST computerized databases. The data were obtained on the same column (MDN-5S) described above. The operating conditions used 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  $\mu$ A; scanning speed 0.5 s over 38 to 400 amu range; split 1:70.

### 2.5 Compound identification

Identification of the oil constituents was performed using the retention indices which were calculated in relation to a homologous series of *n*-alkanes, on a 5% phenyl-/95% dimethylpolysiloxane type column [22], and by comparison of their mass spectra with those published in the literature [23-25], and those of our own database, or comparing their mass spectra with those available in the computerized databases (NIST107 and Wiley139). To obtain the retention indices for each peak, 0.1  $\mu$ L of *n*-alkane mixture (Sigma, C<sub>8</sub>-C<sub>32</sub> standard mixture) was injected under the same experimental conditions reported above. Integration of the total chromatogram (GC-FID), expressed as area percent, without correction factors, has been used to obtain quantitative compositional data.

**Table 2:** Chemical composition of the essential oils obtained from *Eucalyptus deglupta* cultivated in Costa Rica.

Compound <sup>a</sup>	RI <sup>b</sup>	Lit. RI <sup>c</sup>	Class	Leaves (%)	Twigs (%)	Fruits (%)	Identification method <sup>c</sup>
( <i>Z</i> )-Hex-3-enal*	797	797	A	t	-	-	1, 2
( <i>E</i> )-Hex-2-enal*	846	848	A	1.6	0.1	0.1	1, 2
( <i>E</i> )-Hex-2-en-1-ol*	854	855	A	-	-	t	1, 2
( <i>Z</i> )-Hex-2-en-1-ol*	859	859	A	1.0	t	-	1, 2
Hexan-1-ol*	863	863	A	t	t	t	1, 2, 3
3-Methylbutylacetate*	869	868	A	0.2	t	t	1, 2
2-Methylbutylacetate*	875	873	A	-	t	-	1, 2
Heptan-2-ol*	894	892	A	-	t	0.1	1, 2
3-Methyl-2-buten-1-ylacetate*	918	911 <sup>[26]</sup>	A	t	-	-	1, 2
Tricyclene*	921	920	M	-	t	t	1, 2
$\alpha$ -Thujene	924	924	M	0.6	0.4	0.5	1, 2
$\alpha$ -Pinene	932	935	M	16.8	37.2	8.9	1, 2, 3

Fenchene*	945	944	M	t	t	-	1, 2
Camphene	946	948	M	0.2	t	t	1, 2
Thuja -2,4(10)-diene*	953	954	M	-	t	-	1, 2
Sabinene	969	966	M	-	t	-	1, 2
$\beta$ -Pinene	974	979	M	4.1	6.3	1.6	1, 2, 3
6-Methyl-5-hepten-2-one*	981	980	A	t	t	-	1, 2
Myrcene	988	989	M	0.7	0.7	0.5	1, 2
$\alpha$ -Phellandrene	1002	1006	M	32.7	-	20.4	1, 2
$\delta$ -3-Carene*	1008	1009	M	-	9.9	-	1, 2
$\alpha$ -Terpinene	1014	1018	M	0.8	0.1	0.5	1, 2
<i>p</i> -Cymene	1022	1025	M	12.6	19.6	13.4	1, 2
Limonene	1024	1028	M	5.2	2.0	1.9	1, 2, 3
$\beta$ -Phellandrene	1025	1031	M	5.0	0.1	1.4	1, 2
1,8-Cineole	1026	1032	OM	t	0.1	0.8	1, 2, 3
( <i>Z</i> )- $\beta$ -Ocimene	1032	1031	M	t	0.1	t	1, 2
Hept-2-ylacetate*	1038	1039	A	-	-	t	1, 2
( <i>E</i> )- $\beta$ -Ocimene*	1044	1045	M	-	0.4	-	1, 2
$\gamma$ -Terpinene	1054	1053	M	1.4	-	1.0	1, 2
Octan-1-ol*	1063	1065	A	-	t	t	1, 2
<i>cis</i> -Linalool oxide (furananoid)	1067	1068	OM	-	-	t	1, 2
<i>trans</i> -Linalool oxide (furanoid) *	1084	1079	OM	t	-	t	1, 2
<i>p</i> -Mentha-2,4(8)-diene*	1085	1085	M	1.0	-	t	1, 2
Terpinolene	1086	1084	M	-	0.7	4.0	1, 2, 3
<i>p</i> -Cymenene	1089	1090	M	0.1	0.1	0.1	1, 2
Linalool	1095	1098	OM	0.2	0.4	0.2	1, 2, 3
3-Methylbutyl2-methylbutanoate*	1100	1103	A	t	-	0.1	1, 2
Nonanal*	1100	1108	A	-	0.1	-	1, 2
<i>exo</i> -Fenchol	1118	1119	OM	0.1	0.1	t	1, 2
<i>cis-p</i> -Menth-2-en-1-ol	1118	1122	OM	t	0.3	0.6	1, 2
Campholenal	1122	1126	OM	t	0.1	-	1, 2
1-Terpineol*	1130	1130	OM	-	t	-	1, 2
<i>p</i> -Mentha-1,5,8-triene*	1135	1134 <sup>[27]</sup>	M	-	t	-	1, 2
<i>trans</i> -Pinocarveol	1135	1137	OM	-	0.4	t	1, 2
<i>trans-p</i> -Menth-2-en-1-ol	1136	1138	OM	0.2	0.1	0.6	1, 2
<i>cis</i> -Verbenol*	1137	1139	OM	-	t	-	1, 2
Camphene hydrate	1145	1150	OM	t	0.1	t	1, 2
Pinene oxide *	1154	1153	M	-	-	t	1, 2
<i>trans</i> -Pinocamphone*	1158	1156	OM	-	t	-	1, 2
Pinocarvone	1160	1162	OM	t	0.1	t	1, 2
Borneol	1165	1168	OM	0.1	0.1	0.1	1, 2
Terpinen-4-ol	1174	1178	OM	1.2	1.1	1.8	1, 2, 4
<i>m</i> -Cymen-8-ol*	1176	1183	OM	t	-	-	1, 2
<i>p</i> -Cymen-8-ol*	1179	1186	OM	0.1	-	0.3	1, 2
Cryptone	1183	1182	OM	-	0.1	-	1, 2
Dill ether*	1184	1184	OM	-	0.2	-	1, 2
Methyl salicylate*	1190	1191	B	0.1	-	-	1, 2, 3
$\alpha$ -Terpineol	1192	1193	OM	0.3	0.5	0.5	1, 2
<i>cis</i> -Piperitol*	1195	1197	OM	t	0.1	t	1, 2
<i>cis</i> -Sabinol*	1202	1200 <sup>[28]</sup>	OM	-	-	0.6	1, 2
$\alpha$ -Phellandrene epoxide*	1202	1203 <sup>[29]</sup>	OM	0.2	0.3	t	1, 2
<i>trans</i> -Piperitol*	1207	1208	OM	0.1	-	0.3	1, 2
<i>trans</i> -Carveol*	1215	1212	OM	-	0.1	-	1, 2
endo-Fenchyl acetate*	1218	1217	OM	0.1	0.1	0.1	1, 2
<i>trans</i> -3-Caren-2-ol*	1227	1225 <sup>[30]</sup>	OM	-	-	t	1, 2
Carvone*	1239	1242	OM	0.1	-	-	1, 2, 3
Carvotanacetone	1244	1246	OM	0.2	1.2	0.4	1, 2
3-Methylbutylhexanoate*	1246	1250	A	t	t	-	1, 2
Piperitone	1249	1251	OM	-	-	t	1, 2
( <i>E</i> )-Dec-2-enal*	1260	1262	A	-	0.1	-	1, 2
<i>p</i> -Menth-1-en-7-al*	1273	1277	OM	t	-	-	1, 2
<i>neo-iso</i> -3-Thujanol acetate*	1281	1280	OM	-	-	0.1	1, 2
Isobornyl acetate*	1283	1284	OM	0.1	-	-	1, 2
Thymol*	1289	1288		-	-	0.2	1, 2, 3
<i>trans</i> -Sabinyl acetate*	1289	1286	OM	-	0.2	-	1, 2
<i>trans</i> -Linalool oxide acetate* (pyranoid)	1292	1290 <sup>[30]</sup>	OM	-	0.1	-	1, 2
Bornyl acetate	1292	1293 <sup>[31]</sup>	OM	-	0.2	-	1, 2
3-Thujanyl acetate*	1295	1295	OM	-	0.2	-	1, 2
Carvacrol ethyl ether*	1297	197	OM	-	0.1	-	1, 2
Terpinen-4-yl acetate*	1298	1298	OM	0.1	t	-	1, 2

Carvacrol	1298	1305	OM	t	t	0.2	1, 2
Methyl geranate*	1322	1321	OM	0.1	0.2	0.2	1, 2
Myrtenyl acetate*	1324	1330	OM	0.2	0.1	t	1, 2
$\alpha$ -Terpinyl acetate*	1346	1347	OM	1.1	1.5	3.9	1, 2
Neryl acetate*	1359	1358	OM	t	0.1	0.1	1, 2
$\alpha$ -Ylangene	1373	1375	S	0.1	t	0.1	1, 2
$\alpha$ -Copaene	1374	1374	S	-	0.1	0.7	1, 2
Geranyl acetate*	1379	1378	OM	t	t	t	1, 2
<i>trans</i> -Myrtenyl acetate*	1385	1385	OM	t	-	-	1, 2
Benzyl pentanoate*	1396	1394 <sup>[32]</sup>	B	-	0.2	0.1	1, 2
$\alpha$ -Gurjunene	1409	1406	S	0.1	0.2	1.4	1, 2
$\beta$ -Caryophyllene	1417	1416	S	0.8	1.2	5.1	1, 2, 3
$\beta$ -Gurjunene	1431	1429	S	-	-	0.1	1, 2
$\alpha$ - <i>trans</i> -Bergamotene*	1432	1432	S	-	t	-	1, 2
Aromadendrene	1439	1437	S	0.1	0.2	1.1	1, 2
3-Methylbutyloctanoate*	1442	1446	A	t	t	-	1, 2
$\alpha$ -Humulene	1452	1454	S	0.2	0.2	0.8	1, 2, 3
<i>allo</i> -Aromadendrene	1458	1459	S	t	0.1	0.4	1, 2
Dauca-5,8-diene*	1471	1470	S	t	0.2	-	1, 2
Amorpha-4,7(11)-diene*	1479	1478	S	-	-	0.2	1, 2
GermacreneD*	1484	1483	S	-	-	0.2	1, 2
$\beta$ -Selinene	1489	1492	S	-	0.2	1.0	1, 2
Viridiflorene*	1496	1495	S	0.1	0.1	0.5	1, 2
$\alpha$ -Selinene*	1498	1498	S	0.1	t	0.5	1, 2
$\alpha$ -Murolene	1500	1503	S	0.1	t	0.1	1, 2
(3 <i>E</i> ,6 <i>Z</i> )- $\alpha$ -Farnesene*	1508	1507	S	0.1	-	-	1, 2
$\delta$ -Amorphene*	1511	1510	S	-	t	-	1, 2
$\gamma$ -Cadinene	1513	1514	S	t	0.3	0.2	1, 2
<i>trans</i> -Calamenene	1521	1520	S	-	0.1	-	1, 2
$\delta$ -Cadinene	1522	1520	S	0.4	-	1.3	1, 2
Zonarene*	1528	1524	S	0.1	-	-	1, 2
<i>cis</i> -Calamenene*	1528	1525	S	-	-	0.3	1, 2
<i>trans</i> -Cadin-1,4-diene*	1533	1532	S	0.1	0.1	0.5	1, 2
$\alpha$ -Calacorene*	1544	1541	S	t	t	0.2	1, 2
( <i>E</i> )-Nerolidol	1561	1562	OS	4.4	1.3	2.4	1, 2, 3
Palustrol*	1567	1569	OS	-	0.1	0.6	1, 2
Caryophyllene oxide	1582	1582	OS	0.1	0.9	1.7	1, 2
Isoaromadendrene*	1584	1583 <sup>[33]</sup>	S	-	0.9	-	1, 2
Thujopsan-2- $\alpha$ -ol*	1586	1583	OS	0.2	-	-	1, 2
Globulol	1590	1588	OS	-	-	2.7	1, 2
Viridiflorol	1592	1591	OS	-	0.2	0.8	1, 2
Fokienol*	1596	1595	OS	t	-	-	1, 2
Ledol ( <i>epi</i> -Globulol)	1602	1604	OS	0.1	0.2	1.2	1, 2
5- <i>epi</i> -7- <i>epi</i> - $\alpha$ -Eudesmol*	1607	1607	OS	-	-	t	1, 2
Humulene epoxide*	1608	1609	OS	-	0.1	0.3	1, 2
1,10-di- <i>epi</i> -Cubanol*	1618	1617	OS	-	t	0.1	1, 2
1- <i>epi</i> -Cubanol*	1627	1627	OS	0.2	0.4	1.8	1, 2
Caryophylla-4(12),8(13)-dien-5 $\alpha$ -ol*	1639	1635	OS	-	t	1.2	1, 2
Caryophylla-4(12),8(13)-dien-5 $\beta$ -ol*	1639	1636	OS	-	0.1	0.3	1, 2
$\alpha$ -Muurolol (Torreyol) *	1644	1642	OS	-	-	0.1	1, 2
Cubanol*	1645	1643	OS	0.1	0.2	-	1, 2
$\alpha$ -Cadinol*	1652	1656	OS	-	0.1	0.3	1, 2
Selin-11-en-4 $\alpha$ -ol*	1658	1657	OS	-	-	0.4	1, 2
14-Hydroxy-9- <i>epi</i> -( <i>E</i> )-caryophyllene*	1668	1669	OS	-	0.1	-	1, 2
Cadalene*	1675	1673	S	-	t	-	1, 2
Homoisobaeckeol*	1839	1840	B	-	0.1	-	1, 2
Baeckeol*	1861	1862	B	-	0.1	-	1, 2
( <i>Z</i> )-Phytol*	2114	2114	D	-	t	t	1, 2
( <i>E</i> )-Phytylacetate*	2218	2216	D	t	-	-	1, 2
Tricosane*	2300	2300	A	t	t	t	1, 2, 3
1-Heneicosanol*	2365	2362	A	-	-	0.1	1, 2, 3
Tetracosane*	2400	2400	A	-	-	t	1, 2, 3
Pentacosane*	2500	2500	A	-	-	t	1, 2, 3
Heptacosane*	2700	2700	A	-	-	t	1, 2, 3
Nonacosane*	2900	2900	A	-	-	t	1, 2, 3
Chemical classes							
Monoterpenehydrocarbons (M)				81.2	77.6	54.2	
Oxygenatedmonoterpenes (OM)				4.5	8.0	11.0	
Sesquiterpenehydrocarbons (S)				2.3	3.9	14.7	

Oxygenated sesquiterpenes (OS)			5.1	3.7	13.9	
Aliphatics (A)			2.8	0.3	0.4	
Benzenoids (B)			0.1	0.4	0.1	
Diterpenoids (D)			t	t	t	
Identified constituents (%)			96.0	93.9	94.3	

<sup>a</sup>Compounds listed in order of elution from 5% phenyl-/95% dimethylpolysiloxane type column.

<sup>b</sup>RI = Retention index relative to C<sub>8</sub>-C<sub>32n</sub>-alkanes. <sup>c</sup>Lit. RI = J&W, DB-5<sup>[25]</sup>. <sup>d</sup>t = Traces (<0.05%). <sup>e</sup>Method: 1 = Retention index on MDN-5S column; 2 = MS spectra; 3 = Standard. \*Compounds not reported previously.

### 3. Results and Discussion

The essential oils from different morphological parts of *E. deglupta* cultivated in the Central Valley, Costa Rica, were predominantly terpenoid in nature. The identified constituents, their experimental retention indices (RI), their relative percentage concentrations, and the method used for their identification are presented in Table 2. The constituents are listed in order of elution on a MDN-5S column.

The leaf oil of *E. deglupta* consisted largely of monoterpenoids (85.7%). The major constituents were the monoterpene hydrocarbons  $\alpha$ -phellandrene (32.7%),  $\alpha$ -pinene (16.8%), *p*-cymene (12.6%), limonene (5.2%),  $\beta$ -phellandrene (5.0%), and  $\beta$ -pinene (4.1%). The only one prominent sesquiterpenoid was (*E*)-nerolidol (4.4%). The composition of the twig oil was dominated also by monoterpenoids (85.6%) with  $\alpha$ -pinene (37.2%), *p*-cymene (19.6%),  $\delta$ -3-carene (9.9%), and  $\beta$ -pinene (6.3%) as principal constituents. The fruit essential oil was constituted also by monoterpenoids (65.2%) with more quantity of sesquiterpenoids (28.6%) compared with leaf and twig oils. The major monoterpene compounds were  $\alpha$ -phellandrene (20.4%), *p*-cymene (13.4%),  $\alpha$ -pinene (8.9%), terpinolene (4.0%), and  $\alpha$ -terpinyl acetate (3.9%). Among the sesquiterpenoids,  $\beta$ -caryophyllene (5.1%), globulol (2.7%), (*E*)-nerolidol (2.4%), 1-*epi*-cubanol (1.8%), caryophyllene oxide (1.7%),  $\delta$ -cadinene (1.3%), and caryophylla-4(12), 8(13)-dien-5 $\alpha$ -ol (1.2%) are the most significant constituents. The composition of oils from leaves of *E. deglupta* from New Guinea <sup>[16]</sup>, Indonesia <sup>[21]</sup>, Cuba <sup>[18]</sup> and Nigeria <sup>[19]</sup> could suggest each chemotype, characterized by the acyclic sesquiterpenic alcohol named (*E*)-nerolidol (25-66%), whereas the composition of the oils of the plants cultivated in Australia <sup>[16]</sup>, Democratic Republic of Congo <sup>[11]</sup> and Republic of Côte d'Ivoire <sup>[20]</sup> presented two diverse compositions with few quantity of nerolidol and they could be divided into two different chemotypes: one with the oxygenated monoterpenes 1,8-cineole and cryptone as major constituents, and other with high amounts of the monoterpene hydrocarbons  $\alpha$ -phellandrene and *p*-cymene. The oil from Costa Rican samples resembles the Australian (north Queensland) and Ivorian compositions but with some quantitative differences like the presence of a high amounts of  $\alpha$ -pinene. The essential oils extracted from leaves, twigs, and fruits of *E. deglupta* differs in composition not only quantitatively but also qualitatively. The monoterpenoids in leaves and twigs represent more than 85% of the oil, whereas in fruit oil amount to 65% but with higher quantity of sesquiterpenoids (ca. 28-29%). These changes probably are part of the biological variability of the plant, as they are regulated by the chemical processes involving the biosynthesis of secondary metabolites. The monoterpene  $\alpha$ -phellandrene is the major compound in leaf and fruit oils (32.7 and 20.4%, respectively), but it is absent in the twig oil. Another monoterpene,  $\alpha$ -pinene (37.2%), is the major component of the twig oil, accompanied by *p*-cymene (19.6%),  $\beta$ -pinene (6.3%), and  $\delta$ -3-carene (9.9%), but the

latter is absent both in leaf and fruit oils. The twig oil presents minor quantities of several metabolites that are absent in the other oils, such as cryptone, some monoterpene esters, and the benzenoid class of compounds namely baeckeol and homoisobaeckeol.

### 4. Conclusions

The volatile oil from leaves of *E. deglupta* cultivated in Costa Rica was dominated by monoterpene hydrocarbons with  $\alpha$ -phellandrene,  $\alpha$ -pinene, and *p*-cymene as major constituents accompanied by minor amounts of limonene,  $\beta$ -phellandrene, and  $\beta$ -pinene. The chemical composition of this oil resembles the composition of Australian and Ivorian oils, but with some quantitative and qualitative differences that probably could be reflect of its capacity of adaptation to environmental changes.

### 5. Acknowledgments

The authors are grateful to School of Chemistry and Vice-Rectorate for Research (University of Costa Rica) for financial support and to LJ Poveda (School of Environmental Sciences, National University) for his help in identifying plant material.

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