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Phytotoxic effects of *Lantana camara*, *Eucalyptus camaldulensis* and *Eriocephalus africanus* essential oils in weeds of Mediterranean summer crops

Mercedes Verdeguer a, M. Amparo Blázquez b,*, Herminio Boira a

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ABSTRACT

The essential oil composition of *Lantana camara*, *Eucalyptus camaldulensis* and *Eriocephalus africanus* was analyzed by means of GC and GC–MS and bioassayed in order to determine their activity against *Amaranthus hybridus* and *Portulaca oleracea*. *E. camaldulensis* essential oil, with spathulenol as the main compound, was the most effective, completely inhibiting germination and seedling growth on both weeds. The essential oil of *E. africanus*, rich in artemisia ketone, showed activity similar to that of *E. camaldulensis* on *A. hybridus*, but it was not so effective against *P. oleracea*, and *L. camara* essential oil, with high percentages in sesquiterpene hydrocarbons, also showed higher phytotoxic activity against *A. hybridus*, inhibiting its germination and seedling length; however, it showed no effect against *P. oleracea* germination, whereas was effective in significantly reducing its seedling growth at all concentrations assayed. The results suggest the possible use of these essential oils as natural herbicides.

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1. Introduction

The continued use of synthetic herbicides has resulted in herbicide-resistant weeds as well as in negative impacts upon human health and the environment (Vyvyan, 2002). Nowadays, agricultural techniques are focused on sustainable agricultural production. In this sense, allelopathy offers an important tool for selective biological weed management through the production and release of allelochemicals from the leaves, flowers, seeds, stems and roots of plant materials (Weston, 1996).

Lantana camara L. (Verbenaceae), a neotropical aromatic shrub, is considered one of the 10 worst weeds of the world because it infests 14 crops in many tropical and subtropical countries (Oudhia, 2001). However, in Europe it grows as an ornamental plant. Allelopathic effects of *L. camara* on germination and seedling vigour of many agricultural crops, such as rice (Bansal, 1998; Oudhia and Tripathi, 1999), wheat (Oudhia and Tripathi, 2000) and soybean (Oudhia, 1999) have been reported. The leaves, roots and fruits of *L. camara* contain allelochemicals, mainly aromatic alkaloids and phenolic compounds (Ambika et al., 2003). The essential oil composition of *L. camara* leaves from different origins is characterized by a high content of sesquiterpene hydrocarbons (Ngassoum et al., 1999; Ouamba et al., 2006). However, the phytochemical group of the main compound is different depending on the part of the plant used to obtain the essential oil (Khan et al., 2003).

The allelopathic effects of some *Eucalyptus* species (Myrtaceae) have been also studied (May and Ash, 1990; Alves et al., 1999). Essential oils from *Eucalyptus* containing allelochemicals, like 1.8-cineol, limonene or α - and β -pinene are employed in medicine, cosmetic and pharmaceutical industries. In California, the annual vegetation adjacent to *Eucalyptus camaldulensis* Dehnh. is often severely inhibited by allelochemicals released by this species (Del Moral and Muller, 1970).

^a Instituto Agroforestal Mediterráneo, Universidad Politécnica de Valencia, Camino de Vera s/n, C.P. 46022 Valencia, Spain

^b Departament de Farmacologia, Facultat de Farmàcia, Universitat de València, Avda Vicent Andrés Estellés s/n, C.P. 46100 Burjassot, Spain

^{*} Corresponding author. Tel.: +34 96 354 49 45; fax: +34 96 354 49 43.

E-mail addresses: merversa@doctor.upv.es (M. Verdeguer), amparo.blazquez@uv.es (M.A. Blázquez), hboira@eaf.upv.es (H. Boira).

On the other hand, no bioassays or field experiments had been performed to study the allelopathic potential of *Erioce-phalus africanus* L. (Wild Rosemary, Asteraceae), an aromatic shrub native of South Africa, naturalized in most Mediterranean areas as an ornamental plant. Its essential oil composition (Merle et al., 2007), with a high content of artemisia ketone (>56%), a characteristic compound of the essential oils from plants with allelopathic properties of the *Artemisia* genus (Tan et al., 1998; Preston et al., 2002), guided us to select this species to compare its allelopathic potential with that known of *L. camara* and *E. camaldulensis*.

Finally, *Amaranthus hybridus* L. (smooth pigweed) and *Portulaca oleracea* L. (purslane) are two serious weeds in summer crops in the Mediterranean area and are considered very aggressive in tropical and subtropical climates (Holm et al., 1991). So, the aim of the present work was to study the essential oil composition from three populations of *L. camara*, *E. camaldulensis* and *E. africanus* in order to know if these compositions have phytotoxic effects against *A. hybridus* and *P. oleracea* germination and seedling growth.

2. Materials and methods

2.1. Weeds

Mature seeds of annual weeds *A. hybridus* and *P. oleracea* were collected from parent plants growing in fields of Valencia area, in October 2005. The plants were dried for 15 days at room temperature, afterwards the seeds were extracted. Uniform healthy seeds were selected and stored at 4 °C until germination tests.

2.2. Essential oils

Fresh plant materials of *L. camara*, *E. camaldulensis* and *E. africanus* were collected from gardens of Valencia between May 2005 and October 2007 and were subjected to hydrodistillation for 3 h in a Clevenger-type apparatus, yielding 0.04%, 0.71% and 0.43% v/w, respectively, of essential oil. All essential oils were stored at 4 °C until they were analyzed (diluted at 1% v/v in diethyl ether) or their allelopathic potential was tested.

2.3. Gas chromatography

Gas chromatography was performed using a Clarus 500GC Perkin–Elmer apparatus equipped with a flame ionization detector (FID), a Hewlett–Packard HP-1 (cross-linked methyl silicone) capillary column 30 m long and 0.2 mm i.d., with 0.33 μ m film thickness. The column temperature program was 60 °C for 5 min, with 3 °C increases per min to 180 °C, then 20 °C increases per min to 280 °C which was maintained for 10 min. The carrier gas was helium at a flow-rate of 1 ml/min. Both the FID and injector port temperature were maintained at 250 °C and 220 °C respectively.

2.4. Gas chromatography-mass spectrometry

Gas chromatography–mass spectrometry analysis was carried out with a Varian Saturn 2000 equipped with a Varian C.S VA-5MS capillary column 30 m long and 0.25 mm i.d. with 0.25 μ m film thickness. The same working conditions used for GC and split mode injection (ratio 1:25) were employed. Mass spectra were taken over the m/z 28–400 range with an ionizing voltage of 70 eV. Kovats retention index was calculated using co-chromatographed standard hydrocarbons. The individual compounds were identified by MS (Adams, 2007) and their identity was confirmed by comparison of their RIs, relative to C_8-C_{32} n-alkanes, and by comparing their mass spectra and retention times with those of authentic samples or with data already available in the NIST 98 library and in the literature.

2.5. Seed germination and growth seedling tests

Sets of 20 seeds each with five replicates per treatment were germinated in Petri dishes (9 cm diameter) between two layers of filter paper (Whatman No. 1) wetted with 4 ml of distilled water. Essential oils of *L. camara*, *E. camaldulensis* or *E. africanus*, were added at volumes of 0 (control, distilled water), 0.5, 1, 2, and 4 μ l. According previous assays, *A. hybridus* and *P. oleracea* seeds were incubated alternating 30.0 \pm 0.1 °C, 16 h in light and 20.0 \pm 0.1 °C, 8 h in dark. To evaluate the phytotoxic activity of the essential oils, germination and seedling length, data were recorded after 3, 5, 7, 10 and 14 days.

2.6. Statistical analysis

Tests were conducted in a randomized complete design with five replications. Data were submitted to analysis of variance. Percentage values were previously arcsin transformed. The means were compared by Tukey test (P < 0.05).

3. Results

3.1. Chemical composition

A total of 123 compounds were identified by GC and GC/MS from the essential oils of L. camara, E. camaldulensis and E. africanus. The qualitative and quantitative composition of the three species, very different, is given in Table 1 where the compounds are classified by phytochemical groups and listed in order of their elution on a methyl silicone HP-1 column. Thirty-four compounds were identified in L. camara essential oil, accounting for 96% of the total oil composition. The monoterpene fraction commonly found in E. camaldulensis and E. africanus was devoid in the three populations of E. $ext{camara}$ here analyzed but not in other E. $ext{camara}$ species from different geographical origin (Rana et al., 2005). Substantial differences on these fractions were observed in the other two analyzed species. The monoterpene hydrocarbons ranged 7.09% in E. $ext{africanus}$, with $ext{a}$ -pinene (3.09%), $ext{b}$ -pinene (1.65%) and $ext{b}$ -cymene (1.67%) being the major components. This fraction, with 26.38% of the total oil, represented the second most important group on $ext{b}$. $ext{camaldulensis}$ essential oil, with $ext{b}$ -cymene (21.92%) followed by $ext{a}$ -pinene (1.29%) and $ext{b}$ -cymene (1.21%) as the main compounds.

Differences in the oxygenated monoterpenes were also observed between the two species. With the exception of 1,8-cineole, terpinen-4-ol and mirtenal, which were identified in the two essential oils, the oxygenated monoterpenes found in *E. camaldulensis* were not found in *E. africanus* essential oil. This fraction, with 25 identified compounds in *E. camaldulensis*, accounted for 19.86% of the total oil, with the main compounds being cryptone (7.76%), terpinen-4-ol (2.56%), *p*-menth-1-en-7-al (2.09%), 1,8-cineole (1.92%) and cumin aldehyde (1.17%), whereas the 12 oxygenated monoterpenes identified in *E. africanus* accounted for 64.17% of the total oil composition. Artemisia ketone (56.46%) followed by yomogi alcohol (2.99%), artemisia alcohol (1.71%) and pinocarvone (1.13%), not found in *L. camara* or *E. camaldulensis*, were the main compounds of this fraction.

The greater differences comparing the three species appeared in the sesquiterpene hydrocarbons contents. In *L. camara*, it accounted for 88.96% of the total oil, whereas in *E. camaldulensis* only allo-aromadendrene with a percentage of 0.89% was identified and in *E. africanus* with 7 identified compounds, it was 3.64%. With 20 compounds identified, sesquiterpene hydrocarbons constitute the predominant group in *L. camara* essential oil. This fraction contained mainly β -caryophyllene (17.54%), α -humulene (7.43%), γ -muurolene (12.54%) and curcumene compounds α -curcumene (23.09%), γ -curcumene (14.64%) and β -curcumene (4.83%).

In the oxygenated sesquiterpene fraction qualitative and quantitative differences were also observed: zingiberenol (1.26%) and caryophyllene oxide (1.63%) were the main compounds in *L. camara*, whereas spathulenol derivatives (spathulenol 41.46%, isospathulenol 1.39% and spathulenol isomer 1.08%) and isobicyclogermacrenal (1.92%) were the principal oxygenated sesquiterpenes of *E. camaldulensis* populations. Intermedeol (9.59%) and γ -eudesmol (5.64%), not detected in *L. camara* or *E. camaldulensis*, were the main compounds of these fractions in *E. africanus* essential oil.

Oxygenated diterpenes were found in *L. camara* (1.05%) and also in trace amount in *E. africanus*. Finally, a fraction of nonterpenic compounds was detected in *E. camaldulensis* and *E. africanus* (0.52%) essential oils. From this fraction only 5-methyl-3-hexen-2-one and 2-nonanone were identified in trace amounts in *E. camaldulensis*.

3.2. Germination tests

The essential oil of *E. camaldulensis* was the most effective, completely inhibiting both *A. hybridus* and *P. oleracea* seed germination (Table 2) whereas *L. camara* and *E. africanus* essential oils showed different activity depending on the weed assayed. The essential oil of *E. africanus* showed very phytotoxic effects against *A. hybridus* seeds, blocking their germination at all the concentrations applied, while it only reduced significantly *P. oleracea* germination at the highest concentrations (0.5 and 1 μ l/ml). Both concentrations decreased *P. oleracea* germination 23 and 24% respectively.

L. camara essential oil was not active against *P. oleracea* germination. No significant differences were found between the control and the concentrations assayed. On the other hand, this essential oil was effective in reducing *A. hybridus* germination at all the concentrations tested, not showing significant differences in the germination inhibition between concentrations: $0.125 \,\mu$ ml reduced *P. oleracea* germination 93.10%, $0.25 \,\mu$ ml 86.21% and $0.5 \,\mu$ ml and $1 \,\mu$ ml concentrations inhibited germination 94.25% and 96.55%, respectively.

3.3. Seedling growth

As there was no germination of *A. hybridus* and *P. oleracea* seeds treated with *E. camaldulensis* essential oil, there was no growth of these seedlings. The phytotoxic effect of *E. africanus* essential oil on seedlings growth depended on the species tested: in *A. hybridus* it caused a significant decrease in seedlings length, which was nearly 0, with no significant differences within concentrations, while in *P. oleracea* it reduced seedlings length at all the concentrations tested (Fig. 1), showing significant differences between control and the two lower concentrations, and between the lower concentrations and the two highest concentrations: the lower concentrations, 0.125 μ l/ml and 0.25 μ l/ml decreased germination 69.51% and 67.22%, respectively, and concentrations of 0.5 μ l/ml and 1 μ l/ml inhibited germination 80.25% and 82.74%, respectively.

L. camara essential oil was the least active of the oils tested. It showed phytotoxic effects on the seedlings growth of the two species assayed, although its effect was stronger on A. hybridus. In this species the seedling length was significantly

 Table 1

 Constituents of essential oils from Lantana camara, Eucalyptus camaldulensis and Eriocephalus africanus by GC and GC-MS analysis.

Monoterpene hydrocarbons 903 - - 0.24 ± 0.00	Compound	KI	Lantana camara	Eucalyptus camaldulensis	Eriocephalus africanus
Artemiski triene 924 -				26.38	
x-Thugiene 931 - 027±005 - 030±035 camphene 934 - 129±007 3,00±035 camphene 954 - 1 - 1 thus-24(10)-diene 950 - 009±001 - 1 thus-24(10)-diene 950 - 009±001 - 1 thus-24(10)-diene 950 - 1 thus-24(10)-diene 950 - 1 thus-24(10)-diene 957 - 1 thus-24(10)-d			_	-	
α-Pinnen 939 - 1.29 ± 0.07 3.09 ± 0.35 Camphene 954 - - 1 Thuja-2,4(10)-dine 960 - 0.09 ± 0.01 - Verbenene 977 - 1 0.09 ± 0.01 1.55 ± 0.05 Solinene 979 - 1 0.07 ± 0.00 1.55 ± 0.05 - Wyrome 991 - 1 0.09 ± 0.05 - - z-Terpinene 1017 - 0.08 ± 0.05 -			_	-	$\boldsymbol{0.28 \pm 0.02}$
Camphene 954 - 0.09±0.01 - Thusb_2A(10)-dine 960 - t - - Verbenene 967 - t 0.07±0.00 1.85±0.05 - 1.85±0.05 - 1.01±0.00 1.85±0.05 - 1.01±0.00 - 1.01±0.00 - 1.01±0.00 - 1.01±0.00 - - 1.01±0.00 - - 1.01±0.00 - - 1.01±0.00 - - 1.01±0.00 -			_		
Thuja-24(19)-diene	α-Pinene		-	1.29 ± 0.07	$\boldsymbol{3.09 \pm 0.35}$
Verbienee 967 It 0.03 ± 0.01 0.03 ± 0.01 0.03 ± 0.01 0.03 ± 0.01 1.65 ± 0.05 0.03 ± 0.01 1.65 ± 0.05 0.03 ± 0.01 1.65 ± 0.05 0.03 ± 0.01 1.65 ± 0.05 0.05 0.07 ± 0.00 1.65 ± 0.05 0.05			-	-	t
Sabinene 977 - t 0.03 ± 0.00 1.65 ± 0.05 Myrcene 991 - t 0.13 ± 0.01 Alphellandrene 1006 - 0.10 ± 0.07 - e-Treplinene 1017 - 0.08 ± 0.05 - p-Cymene 1026 - 1.21 ± 0.10 - Humonene 1028 - 1.21 ± 0.10 - Humonene 1028 - 1.21 ± 0.10 - Humonene 1080 - 1.01 ± 0.00 - Humonene 1085 - 0.05 ± 0.02 - Humonene 1085 - 0.05 ± 0.02 - Vomogal akolud 933 - t t - Vomogal akolud 933 - t t - 2.99 ± 0.17 3.54 ± 1.99 Artemisa akolud 1076 - 0.07 ± 0.01 - 4.64 ± 1.99 - 1.12 ± 0.13 - 1.12 ± 0.13 - 1.12 ± 0.13 -	Thuja-2,4(10)-diene		-	0.09 ± 0.01	-
β-Finnen	Verbenene	967	-	t	-
Mycene 991 − t 0.10±0.07 − α- Freliniene 1017 − 0.08±0.05 − ρ-Cymene 1026 − 2.19±1.61 1.67±0.18 μ Commene 1028 − 1.21±0.10 − Limonene 1060 − 0.19±0.08 t γ-Terpinene 1060 − 0.19±0.08 t m-Cymenene 1085 − 0.19±0.08 t Debydro-18-Crancel 93 − t − Yomogi alcohol 996 − − 2.99±0.17 18-Cincole 1033 − 1.92±0.32 0.06±0.00 Artemisia ketone 1062 − − 2.09±0.11 18-Cincole 1033 − 1.92±0.32 0.06±0.00 Artemisia alcohol 1082 − − 1.71±0.13 trans-finatiol oxide 1062 − 0.72±0.11 − Linalool 1000 − 0.46±0.19	Sabinene	977	-	t	0.03 ± 0.01
α-Phellanderen 1006 - 0.10±0.07 - α-Terpinene 1026 - 2.192±1.61 1.67±0.18 σ-Cymene 1026 - 2.192±1.61 1.67±0.18 c-Cymene 1026 - 1.21±0.10 - Limonene 1030 - 1.11±0.17 t γ-Terpinen 1060 - 0.19±0.08 t σ-Cymenene 1085 - 0.05±0.02 - Debtydro-1.8-Cincole 993 - t - 2.99±0.17 Comogiando monterpenes 993 - t - 2.99±0.17 - 2.99±0.17 Comogia Calcolo 996 - - - 2.92±0.32 0.06±0.00 - - 2.92±0.32 0.06±0.00 - - 2.92±0.32 0.06±0.00 - - 2.92±0.32 0.06±0.00 - - 2.64±0.00 - - 2.64±0.00 - - 2.64±0.00 - - - -<	β-Pinene	979	-	0.07 ± 0.00	1.65 ± 0.05
a-Terpinene 1017 −	Myrcene	991	-	t	0.13 ± 0.01
p-Cymene 1028 - 2192±161 1.67±0.18 0-0-Cymene 1028 - 1.21±0.10 -	α-Phellandrene	1006	=	0.10 ± 0.07	-
0-Cymene 1028 - 1.21±0.10 - Limonene 1030 - 0.19±0.08 t m-Cymenee 1065 - 0.19±0.08 t m-Cymenee 1085 - 0.05±0.02 - Oxygenated monoterpenes - 19.86 64.17 Delydro-1,8-Cincole 936 - - 2.92±0.17 1,8-Cincole 1033 - - 2.29±0.17 1,8-Cincole 1033 - - - 56.46±1.99 cta-Linalod skote 1066 - - - 56.46±1.99 - cta-Inalod skote 1082 -	α-Terpinene	1017	-	0.08 ± 0.05	-
Limonene 1030 - 1.11±0.17 t γ-Terpinene 1060 - 0.19±0.08 t σ-Y-Terpinene 1085 - 0.05±0.02 - Dehytor-18-Cincole 993 - t - 2.99±0.17 Dehytor-18-Cincole 993 - t - 2.99±0.17 1.8-Cincole 1033 - 1.92±0.32 0.06±0.00 Artemisia ketone 1062 - - 56.46±1.99 cis-Linalool oxide 1076 - - 1.71±0.13 Artemisia alcohl 1082 - - 1.71±0.13 Artemisia alcohl 11082 - - 1.71±0.13 Artemisia alcohl 11082 - - 1.71±0.13 Artemisia alcohl 11082 - 0.90±0.02 - cis-Phemtha-2-Ri-lol 1126 - 0.07±0.01 - cis-Phemtha-2-Ri-lol 1139 - 0.19±0.03 - - -	p-Cymene	1026	-	21.92 ± 1.61	1.67 ± 0.18
Limonene 1030 - 1.11±0.17 t γ-Terpinene 1060 - 0.19±0.08 t σ-Y-Terpinene 1085 - 0.05±0.02 - Dehytor-18-Cincole 993 - t - 2.99±0.17 Dehytor-18-Cincole 993 - t - 2.99±0.17 1.8-Cincole 1033 - 1.92±0.32 0.06±0.00 Artemisia ketone 1062 - - 56.46±1.99 cis-Linalool oxide 1076 - - 1.71±0.13 Artemisia alcohl 1082 - - 1.71±0.13 Artemisia alcohl 11082 - - 1.71±0.13 Artemisia alcohl 11082 - - 1.71±0.13 Artemisia alcohl 11082 - 0.90±0.02 - cis-Phemtha-2-Ri-lol 1126 - 0.07±0.01 - cis-Phemtha-2-Ri-lol 1139 - 0.19±0.03 - - -	o-Cymene	1028	-	1.21 ± 0.10	-
in-Cymenene 1085 - 0.05 ± 0.02 - Dehydro-1.8-Cincole 993 - t - 2.99 ± 0.17 Vomogi alcohol 996 - - 2.99 ± 0.17 2.99 ± 0.17 Vomogi alcohol 1033 - 1.92 ± 0.32 0.06 ± 0.00 Artemisia ketone 1062 - - 56.46 ± 1.99 cs-1.01 - 56.46 ± 1.99 cs-1.01 - 66.40 0.00 - 46.40 ± 1.99 cs-1.01 - 66.40 0.00 - 46.40 ± 1.99 cs-1.01 - 46.40 ± 1.99 cs-1.01 - 46.40 ± 1.99 cs-1.01 - - 46.40 ± 1.99 cs-1.01 - - 46.40 ± 1.99 cs-1.01 - - - 46.40 ± 1.99 cs-1.01 -<		1030	_	1.11 ± 0.17	t
m-Cymenene 1085 - 0.05 ± 0.02 - Orygenated monoterpenes - 1 9.86 6.17 Debydro-1.8-Cincole 993 - t - 2.99 ± 0.17 Yomogi alcohol 996 - - 2.99 ± 0.17 2.99 ± 0.17 1.8-Cincole 1033 - 1.92 ± 0.32 0.06 ± 0.00 Artemisia ketone 1062 - - 56.46 ± 1.99 cis-landol oxide 1076 - 0.07 ± 0.01 - Artemisia ketone 1082 - 0.07 ± 0.01 - Artemisia ketone 1082 - 0.07 ± 0.01 - Artemisia ketone 1082 - 0.09 ± 0.06 - 1.01 Artemisia ketone 1082 - 0.09 ± 0.06 - 1.01 - 1.01 - 4.01 - 4.01 - - 4.01 - - - - - - 1.03 - - - - - - - - - - -	γ-Terpinene	1060	_	0.19 ± 0.08	t
Oxygenated monoterpenes - 1986 64.17 Dehydro-1.8-Cincole 993 - t - 2.99 ± 0.17 Vomogi alcohol 996 - - 2.99 ± 0.17 1.8-Cincole 1032 - 1.92 ± 0.32 0.06 ± 0.00 1.00 6.64 ± 1.59 1.71 ± 0.13 1.71 ± 0.10 1.71 ± 0.13 1.71 ± 0.10 <td></td> <td>1085</td> <td>_</td> <td></td> <td>_</td>		1085	_		_
Dehydro-1.8-Cincole 993 -					
Vomogia alcohol 996 - - 2.99 ± 0.17 1.8-Cincole 1033 - 1.92 ± 0.32 0.06 ± 0.00 Artemisia alcohol 1062 - - 56.46 ± 1.99 cis-linalool oxide 1088 - 0.09 ± 0.06 - Linalool 1100 - 0.46 ± 0.19 - cis-Thujone 1106 - 0.07 ± 0.01 - cis-Phenth-2-en-1-ol 1126 - 0.09 ± 0.02 - -c-Campholenal 1130 - 0.39 ± 0.03 - cis-Phentha-2-8, diena-1-ol 1139 - 0.19 ± 0.03 - cis-Phentha-2-8, diena-1-ol 1139 - 0.03 ± 0.03 - rours-P-Menth-2-en-1-ol 1141 - - 0.55 ± 0.07 brons-p-Menth-2-en-1-ol 1143 - - 0.03 ± 0.01 - Verboncove 1186 - - - 1.13 ± 0.15 Verpiner 1186 - - 0.03 ± 0.02 <			-		64.17
1.3-Cincole 1033		993	-	t	-
Artemisia ketone 1062 - - 0.07 ± 0.01 - Artemisia alcohol 1082 - - 1.71 ± 0.13 trons-Linalod oxide 1088 - 0.09 ± 0.06 - Linalool 1100 - 0.46 ± 0.19 - cis-Fulpine 1106 - 0.07 ± 0.01 - cis-P-Menth-2-en-1-ol 1126 - 0.09 ± 0.02 - ε-S-p-Menth-2-cn-1-ol 1130 - 0.39 ± 0.03 - cis-p-Menth-2-cn-1-ol 1139 - 0.19 ± 0.03 - cis-p-Menth-2-cn-1-ol 1143 - 0.39 ± 0.01 - trons-p-Menth-2-cn-1-ol 1143 - - 0.55 ± 0.07 trans-p-Menth-2-cn-1-ol 1143 - - 1.11 ± 0.15 rors-p-Gende 1166 - - 1.11 ± 0.15 rors-p-Gende 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1180 - - 0.68 ± 0.06 - <td>Yomogi alcohol</td> <td>996</td> <td>-</td> <td>-</td> <td>2.99 ± 0.17</td>	Yomogi alcohol	996	-	-	2.99 ± 0.17
cis-Linalool oxide 1076 - 0.07 ± 0.01 - Artemisia alcohol 1082 - - 0.09 ± 0.06 - Linalool 1100 - 0.46 ± 0.19 - cis-Thujone 1106 - 0.07 ± 0.01 - cis-Phenth-2-en-1-ol 1126 - 0.09 ± 0.02 - 2-Campholeal 1130 - 0.09 ± 0.02 - 2-Campholeal 1130 - 0.39 ± 0.03 - cis-Phenth-2-en-1-ol 1141 - - 0.55 ± 0.07 trans-Pincarveol 1141 - - 0.55 ± 0.07 trans-Pincarveol 1161 - - 1 Pincarvene 1166 - - 0.03 ± 0.01 - Ferpincer-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 - Cryptone 1185 - - 0.68 ± 0.06 - - 0.68 ± 0.06 - - 0.68 ± 0.06 - -	1,8-Cineole	1033	-	1.92 ± 0.32	0.06 ± 0.00
Artemisia alcohol 1088 - 0.09±0.06 - Linalool 1100 - 0.46±0.19 - cis-Thujone 1106 - 0.07±0.01 - cis-P.Menth-2-en-1-ol 1126 - 0.09±0.02 - ε-Campholenal 1130 - 0.39±0.03 - cis-p-Menth-2-en-1-ol 1141 - - 0.55±0.07 trans-P-inccarveol 1141 - - - 0.55±0.07 trans-P-inccarveol 1161 - - - 1.33±0.15 - Pinocarvone 1166 - - 1.13±0.15 - Terpinen-4-ol 1180 - 2.56±0.43 0.03±0.01 - Cryptone 1185 - <td>Artemisia ketone</td> <td>1062</td> <td>-</td> <td>-</td> <td>56.46 ± 1.99</td>	Artemisia ketone	1062	-	-	56.46 ± 1.99
Artemisia alcohol 1088 - 0.09±0.06 - Linalool 1100 - 0.46±0.19 - cis-Thujone 1106 - 0.07±0.01 - cis-P-Menth-2-en-1-ol 1126 - 0.09±0.02 - sc-g-Menth-2-en-1-ol 1130 - 0.39±0.03 - sc-y-Menth-2-en-1-ol 1141 - - 0.5±0.07 trans-P-Menth-2-en-1-ol 1143 - - - Nerol oxide 1161 - - t - Pinocarvone 1166 - - t 1.13±0.15 - Terpinen-4-ol 1180 - - - t - Cryptone 1185 - - - 0.68±0.06 - Artemisia ketone isomer 1186 - - - 0.68±0.06 -Terpineo 1192 - 0.93±0.11 - - Myttenol 1199 - t<	cis-Linalool oxide	1076	_	0.07 ± 0.01	_
trans-Linalool oxide 1088			_	_	1.71 ± 0.13
Linalool 1106 - 0.46 ± 0.19 - cis'-Pulone 1106 - 0.07 ± 0.01 - cis'-P.Menth-2-en-1-ol 1126 - 0.09 ± 0.02 - ac-Campholenal 1130 - 0.39 ± 0.03 - cis'-P.Mentha-2-B.dien-1-ol 1139 - 0.19 ± 0.03 - rans-PMenth-2-en-1-ol 1141 - - 0.55 ± 0.07 rans-PMenth-2-en-1-ol 1161 - - - Pinocarvone 1166 - - 1.13 ± 0.15 Pinocarvone 1186 - - 1.13 ± 0.15 Terpinen-4-ol 1180 - - 0.68 ± 0.03 0.03 ± 0.01 Cryptone 1185 - - 7.76 ± 0.62 - 1.13 ± 0.15 Artenisia ketone isomer 1186 - - 0.93 ± 0.15 - 0.68 ± 0.06 Artenisia ketone isomer 1180 - - 0.93 ± 0.15 - 1 0.45 ± 0.02 0.02			_	0.09 ± 0.06	
cis-Thujone 1106 - 0.07 ± 0.01 - cis-p-Menth-2-en-1-ol 1126 - 0.99 ± 0.02 - α-Campholenal 1130 - 0.19 ± 0.03 - rums-Pincarveol 1141 - - 0.55 ± 0.07 trans-p-Menth-2-en-1-ol 1143 - 0.36 ± 0.01 - Nerol oxide 1166 - - t Phenth-2-en-1-ol 1186 - - 1.13 ± 0.15 Nerol oxide 1166 - - 1.13 ± 0.15 Piccarvone 1186 - - 1.13 ± 0.15 Cryptone 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1186 - - - - Artemisia ketone isomer 1192 - 0.93 ± 0.15 - </td <td></td> <td></td> <td>_</td> <td></td> <td>_</td>			_		_
cis-p-Menth-2-en-1-ol 1126 - 0.09 ± 0.02 - α-Campholenal 1139 - 0.39 ± 0.03 - cis-p-Mentha-2,8.dien-1-ol 1139 - 0.19 ± 0.03 - trans-P-Menth-2-en-1-ol 1141 - - 0.55 ± 0.07 rans-p-Menth-2-en-1-ol 1143 - - t Nerol oxide 1166 - - t Pinocarvone 1166 - - 1.13 ± 0.15 Terpinen-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1185 - - - 0.68 ± 0.06 Artemisia ketone isomer 1186 - - 0.03 ± 0.15 - - Artemisia ketone isomer 1186 - - 0.03 ± 0.15 - - 4.5 ± 0.02 Myrtenal 1197 - t t 0.03 ± 0.01 - 4.5 ± 0.02 Myrtenal 1199 - - t 0.04 ± 0.02 -			_		_
α-Campholenal 1130 - 0.39 ± 0.03 - cis-p-Mentha-2,8.dien-1-ol 1139 - 0.19 ± 0.03 - rams-Pinocarveol 1141 - - 0.55 ± 0.07 trans-p-Menth-2-en-1-ol 1143 - 0.36 ± 0.01 - Nerol oxide 1166 - - 1.13 ± 0.15 Picoravone 1166 - - 1.13 ± 0.15 Cryptone 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 Ar-Terpine-4-ol 1192 - 0.93 ± 0.15 - Artemisia ketone isomer 1186 - - 0.85 ± 0.06 - Artemisia ketone isomer 1186 - - 0.93 ± 0.15 - - Artemisia ketone isomer 1189 - 0.93 ± 0.15 - - 0.68 ± 0.06 - Artemisia ketone isomer 1280 - 0.80 ± 0.01 - - 0.02 -					
cks-p-Mentha-2.8,dien-1-ol trans-Pinocarveol 1141 - 0.55 ± 0.07 trans-Pinocarveol 1141 - 0.36 ± 0.01 - Nerol oxide 1161 - - t Pinocarvone 1166 - - 1.13 ± 0.15 Terpinen-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1185 - - 0.68 ± 0.06 - Artemisia ketone isomer 1186 - - - 0.88 ± 0.06 A-Terpineol 1197 - t 0.45 ± 0.02 Myrtenol 1199 - t 0.02 0.02 0.03 0.01 0.02 0.02 0.03 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.02					_
trans-Pinocarveol 1141 - - 0.55 ± 0.07 trans-Pinocarvone 1161 - - 1 Pinocarvone 1166 - - 1.13 ± 0.15 Terpinen-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1185 - 7-6 ± 0.62 - Artemisia ketone isomer 1185 - - 0.68 ± 0.06 a-Terpineol 1192 - 0.93 ± 0.15 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 - Artemisia ketone isomer 1180 - - 0.03 ± 0.01 - Artemisia ketone isomer 1180 - - 0.03 ± 0.01 - 0.045 ± 0.02 - Werbend 120 - - 1 0.01 ± 0.00 - 0	•		_		_
transp-Menth-2-en-1-ol 1143 - 0.36 ± 0.01 - Nerol oxide 1161 - - t Pinocarvone 1166 - - 1.13 ± 0.15 Terpinen-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 α-Terpineol 1192 - 0.93 ± 0.15 - Myrtenal 1199 - t 0.45 ± 0.02 Myrtenol 1199 - t t 0.45 ± 0.02 Myrtenol 1199 - t t - t 0.45 ± 0.02 t 1.02 0.02					0.55 + 0.07
Nerol oxide 1161 - - 1.13 ± 0.15 Pinocarvone 1166 - - 1.13 ± 0.15 Terpinen-4-ol 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1185 - - 0.68 ± 0.06 α-Terpineol 1192 - 0.93 ± 0.15 - Myrtenol 1199 - - 1 Verbenone 1208 - 0.0 - w-Cumenol 1230 - 0.10 ± 0.00 - Cumin aldehyde 1242 - 1.17 ± 0.10 - Carvone 1245 - t - - Carvone 1245 - t - - Carvotanacetone 1249 - 0.07 ± 0.01 - - Piperitone 1255 - 0.10 ± 0.00 - - P-Menth-1-en-7-al 1279 - 0.29 ± 0.47 - - Carvacol 1302					
Pinocarvone 1166 - - 1.13 ± 0.15 Terpinen-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 α-Terpineol 1192 - 0.93 ± 0.15 - Myrtenal 1197 - t 0.45 ± 0.02 Myrtenol 1199 - - t Verbenone 1208 - 0.08 ± 0.01 - werbenone 1208 - 0.08 ± 0.01 - m-Cumenol 1230 - 0.10 ± 0.00 - cumin aldehyde 1245 - t - Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 -	-		-	0.36 ± 0.01	
Terpinen-4-ol 1180 - 2.56 ± 0.43 0.03 ± 0.01 Cryptone 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1186 - - 0.68 ± 0.06 α-Terpineol 1192 - 0.93 ± 0.15 - Myrtenal 1199 - t 0.45 ± 0.02 Myrtenol 1199 - t t Verbenone 1208 - 0.08 ± 0.01 - m-Cumenol 1230 - 0.10 ± 0.00 - Curvina idehyde 1242 - 1.17 ± 0.10 - Carvone 1245 - t - - Carvone 1249 - 0.07 ± 0.01 - - Piperitone 1255 - 0.10 ± 0.00 - - Piperitone 1255 - 0.10 ± 0.00 - - 2-Terpinen-7-al 1289 - 0.07 ± 0.01 - - - -			-	-	
Cryptone 1185 - 7.76 ± 0.62 - Artemisia ketone isomer 1186 - - 0.93 ± 0.15 - α-Terpineol 1192 - 0.93 ± 0.15 - Myrtenal 1197 - t 0.45 ± 0.02 Myrtenol 1199 - - t Verbenone 1208 - 0.08 ± 0.01 - m-Cumenol 1230 - 0.10 ± 0.00 - Curvini aldehyde 1245 - t - Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - A-Terpinen-7-al 1285 - t - Carvacrol 1302 - 0.38 ± 0.06 - Carvacrol 1302 - 0.89 ± 0.11 -			-	-	
Artemisia ketone isomer			-		
α-Terpineol 1192 - 0,93 ± 0,15 - Myrtenal 1197 - t 0,45 ± 0,02 Myrtenol 1199 - - t Verbenone 1208 - 0,08 ± 0,01 - m-Cumenol 1230 - 0,10 ± 0,00 - Cumin aldehyde 1242 - 1,17 ± 0,10 - Carvone 1245 - t - Carvotanacetone 1249 - 0,07 ± 0,01 - Piperitone 1255 - 0,10 ± 0,00 - p-Menth-1-en-7-al 1279 - 2,09 ± 0,47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0,38 ± 0,06 - Carvacrol 1302 - 0,38 ± 0,06 - Granyl acetate 1380 - t - Geranyl acetate 1380 - - 0,11 ± 0,01 Sesqu	~ .		-	7.76 ± 0.62	
Myrtenal 1197 - t 0.45 ± 0.02 Myrtenol 1199 - - t Verbenone 1208 - 0.08 ± 0.01 - m-Cumenol 1230 - 0.10 ± 0.00 - Curvone 1245 - 1.17 ± 0.10 - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 0.07 ± 0.01 - p-Menth-1-en-7-al 1285 - t - Carvacrol 1302 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - Geranyl acetate 1330 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - -			-		0.68 ± 0.06
Myrtenol 1199 - - t Verbenone 1208 - 0.08 ± 0.01 - m-Cumenol 1230 - 0.10 ± 0.00 - Curvin 1242 - 1.17 ± 0.10 - Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Carvacrol 1302 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-0xo-p-Menth-1-en-7-al 1335 - t - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 - - 0.11 ± 0.01 - - - - - - - - - - -	•	1192	-	0.93 ± 0.15	-
Verbenone 1208 - 0.08 ± 0.01 - m-Cumenol 1230 - 0.10 ± 0.00 - Cumin aldehyde 1242 - 1.17 ± 0.10 - Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - Geranyl acetate 1380 - t - - Sequiterpene hydrocarbons 88.96 0.89 3.64 - α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - - β-Elemene 1393 3.45 ± 0.65	Myrtenal	1197	-	t	0.45 ± 0.02
m-Cumenol 1230 - 0.10 ± 0.00 - Cumin aldehyde 1242 - 1.17 ± 0.10 - Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - - β-Elemene 1393 3.45 ± 0.65 - <	Myrtenol	1199	-	-	t
Cumin aldehyde 1242 - 1.17 ± 0.10 - Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - P-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - t - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 - - 0.11 ± 0.01 - - 0.11 ± 0.01 - - 0.11 ± 0.01 - - - 0.11 ± 0.01 - - - - - - - - - - - - -	Verbenone	1208	-	0.08 ± 0.01	_
Carvone 1245 - t - Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - t - - Geranyl acetate 1380 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 8.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - - β-Elemene 1393 3.45 ± 0.65 - - - - Italiacene 1404	m-Cumenol	1230	-	0.10 ± 0.00	_
Carvotanacetone 1249 - 0.07 ± 0.01 - Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α -Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - t - Sesquiterpene hydrocarbons 88.96 0.89 3.64 α -Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β -Bourbonene 1388 0.24 ± 0.16 - - - β -Bourbonene 1388 0.24 ± 0.16 - - - β -Bourbonene 1393 3.45 ± 0.65 - - - β -Elemene 1494 0.78 ± 0.48 - - - Sesquithujene	Cumin aldehyde	1242	=	1.17 ± 0.10	_
Piperitone 1255 - 0.10 ± 0.00 - p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - t - - Geranyl acetate 1380 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 - α-Copaene 1378 0.25 ± 0.17 - 0.11 ± 0.01 - β-Bourbonene 1388 0.24 ± 0.16 - - - - β-Bourbonene 1393 3.45 ± 0.65 - - - -	Carvone	1245	-	t	_
p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - β-Elemene 1393 3.45 ± 0.65 - - Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 -	Carvotanacetone	1249	_	0.07 ± 0.01	_
p-Menth-1-en-7-al 1279 - 2.09 ± 0.47 - α-Terpinen-7-al 1285 - t - Thymol 1293 - 0.38 ± 0.06 - Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - β-Elemene 1393 3.45 ± 0.65 - - Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 -		1255	_		_
α-Terpinen-7-al1285-t-Thymol1293- 0.38 ± 0.06 -Carvacrol1302- 0.98 ± 0.11 -3-oxo-p-Menth-1-en-7-al1335-t-Geranyl acetate1380 0.11 ± 0.01 Sesquiterpene hydrocarbons88.96 0.89 3.64 α-Copaene1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene1388 0.24 ± 0.16 β-Elemene1393 3.45 ± 0.65 Italicene1404 0.78 ± 0.48 Sesquithujene1405 0.84 ± 0.17 α-Cedrene1413 0.64 ± 0.07 β-Caryophyllene141917.54 ± 0.56 -1.27 ± 0.50 β-Copaene1432 0.05 ± 0.00 α-trans-Bergamotene1436t cis -β-Farnesene1445 0.73 ± 0.01 α-Humulene1457 7.43 ± 0.64 - 0.09 ± 0.05 $allo$ -Aromadendrene1464- 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene1467 0.22 ± 0.02 β-Acoradiene1470t			_		_
Thymol 1293 - 0.38 ± 0.06 - 0.98 ± 0.11 - 0.38 ± 0.06 - 0.98 ± 0.11 - 0.30 ± 0.98 ± 0.11 - 0.30 ± 0.98 ± 0.11 - 0.30 ± 0.98 ± 0.11 - 0.30 ±	•		_		_
Carvacrol 1302 - 0.98 ± 0.11 - 3-oxo-p-Menth-1-en-7-al 1335 - t - Geranyl acetate 1380 - t - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - β-Elemene 1393 3.45 ± 0.65 - - Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 - - α-trans-Bergamotene 1436 t - - α-Humulene 1445 0.73 ± 0.01 - - α-Humulene 1457 7.43 ± 0.64	•		_		_
3-oxo-p-Menth-1-en-7-al Geranyl acetate 1335 - t - Geranyl acetate 1380 - t - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - - β-Elemene 1393 3.45 ± 0.65 - - - - β-Elemene 1404 0.78 ± 0.48 - - - - Italicene 1404 0.78 ± 0.48 - - - - Sesquithujene 1405 0.84 ± 0.17 - - - - β-Caryophyllene 1413 0.64 ± 0.07 - - - - β-Copaene 1432 0.05 ± 0.00 - - - - α-trans-Bergamotene 1436 t - - - - α-Humulene 1445 0.7			_		_
Geranyl acetate 1380 - - 0.11 ± 0.01 Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - β-Elemene 1393 3.45 ± 0.65 - - Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 - - - α-trans-Bergamotene 1436 t - - - α-Humulene 1457 7.43 ± 0.64 - - - α-Humulene 1457 7.43 ± 0.64 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - - <td></td> <td></td> <td>_</td> <td></td> <td>_</td>			_		_
Sesquiterpene hydrocarbons 88.96 0.89 3.64 α-Copaene 1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene 1388 0.24 ± 0.16 - - β-Elemene 1393 3.45 ± 0.65 - - Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 - - α-trans-Bergamotene 1436 t - - cis-β-Farnesene 1445 0.73 ± 0.01 - - α-Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - - β-Acoradiene 1470			_		0.11 ± 0.01
α-Copaene1378 0.25 ± 0.17 - 0.17 ± 0.10 β-Bourbonene1388 0.24 ± 0.16 β-Elemene1393 3.45 ± 0.65 Italicene1404 0.78 ± 0.48 Sesquithujene1405 0.84 ± 0.17 α-Cedrene1413 0.64 ± 0.07 β-Caryophyllene1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene1432 0.05 ± 0.00 α-trans-Bergamotene1436tcis-β-Farnesene1445 0.73 ± 0.01 α-Humulene1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene1464- 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene1467 0.22 ± 0.02 β-Acoradiene1470t	Geranyi acetate	1500	_	_	0.11 ± 0.01
β-Bourbonene 1388 0.24 ± 0.16 - - β-Elemene 1393 3.45 ± 0.65 - - Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 - - α-trans-Bergamotene 1436 t - - cis-β-Farnesene 1445 0.73 ± 0.01 - - α-Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - β-Acoradiene 1470 t - -	Sesquiterpene hydrocarbons		88.96	0.89	3.64
β-Elemene 1393 3.45 ± 0.65	α-Copaene	1378	$\textbf{0.25} \pm \textbf{0.17}$	_	0.17 ± 0.10
β-Elemene 1393 3.45 ± 0.65	β-Bourbonene	1388	$\textbf{0.24} \pm \textbf{0.16}$	_	_
Italicene 1404 0.78 ± 0.48 - - Sesquithujene 1405 0.84 ± 0.17 - - α -Cedrene 1413 0.64 ± 0.07 - - β -Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β -Copaene 1432 0.05 ± 0.00 - - α -trans-Bergamotene 1436 t - - α -Farnesene 1445 0.73 ± 0.01 - - - α -Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α -Acoradiene 1467 0.22 ± 0.02 - - - β -Acoradiene 1470 t - - -	•			_	_
Sesquithujene 1405 0.84 ± 0.17 - - α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 - - α-trans-Bergamotene 1436 t - - cis-β-Farnesene 1445 0.73 ± 0.01 - - α-Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - β-Acoradiene 1470 t - -				_	_
α-Cedrene 1413 0.64 ± 0.07 - - β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00 - - α -trans-Bergamotene 1436 t - - cis-β-Farnesene 1445 0.73 ± 0.01 - - - α -Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α -Acoradiene 1467 0.22 ± 0.02 - - β -Acoradiene 1470 t - -				_	_
β-Caryophyllene 1419 17.54 ± 0.56 - 1.27 ± 0.50 β-Copaene 1432 0.05 ± 0.00				_	_
β-Copaene 1432 0.05 ± 0.00				_	1.27 ± 0.50
α-trans-Bergamotene 1436 t - - cis -β-Farnesene 1445 0.73 ± 0.01 - - α-Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 $allo$ -Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - β-Acoradiene 1470 t - -				_	1.27 ± 0.30
cis-β-Farnesene 1445 0.73 ± 0.01 - - α-Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - β-Acoradiene 1470 t - -					
α-Humulene 1457 7.43 ± 0.64 - 0.09 ± 0.05 allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - β-Acoradiene 1470 t - -					
allo-Aromadendrene 1464 - 0.89 ± 0.21 0.03 ± 0.03 α-Acoradiene 1467 0.22 ± 0.02 - - β-Acoradiene 1470 t - -				-	0.00 + 0.05
α -Acoradiene 1467 0.22 ± 0.02				- 0.00 + 0.21	
β-Acoradiene 1470 t – –				0.89 ± 0.21	0.03 ± 0.03
·				-	-
(continued on next nas	β-Acoradiene	1470	t	-	-
					(continued on next page)

Table 1 (continued)

	Compound	KI	Lantana camara	Eucalyptus camaldulensis	Eriocephalus africanus
14.64 ± 1.06		1479	12.54 ± 1.43	-	-
Significant	α-Curcumene	1480	23.09 ± 2.10	-	_
x-Murolene 1500 0.35 ± 0.03 - <td>γ-Curcumene</td> <td>1482</td> <td>14.64 ± 1.06</td> <td>-</td> <td>_</td>	γ-Curcumene	1482	14.64 ± 1.06	-	_
x-Murolene 1500 0.35 ± 0.03 - <td>Bicyclogermacrene</td> <td>1500</td> <td>_</td> <td>-</td> <td>1.48 ± 0.29</td>	Bicyclogermacrene	1500	_	-	1.48 ± 0.29
β-Curcumene		1500	$\textbf{0.35} \pm \textbf{0.03}$	_	_
β-Curcumene	β-Bisabolene	1507	0.67 ± 0.06	_	_
7-grig-Se-Selimene 1525	•	1518	4.83 ± 0.38	_	_
β-Sequiphellandrene 1525 0.68 ± 0.04 - - 0.30 ± 0.06 Oxygenated sequirerpenes 1526 - - 0.30 ± 0.03 - 10.11 - [proxy-Calamenene 1492 - 0.59 ± 0.03 - 16.55 ± 0.29 Liguloxide 1536 - - 0.65 ± 0.29 1.26 ± 0.03 2.25 ± 0.03 - 1.26 ± 0.03 2.25 ± 0.03 - 1.26 ± 0.03 - 1.26 ± 0.03 2.25 ± 0.03 - 1.26 ± 0.03 2.25 ± 0.03				_	0.30 ± 0.06
ò-Cadinene 1526 − − 0.30 ± 0.006 Oxygenated sequitrepness 6.21 48.27 21.26 I 10,11-epoxy-Calamenene 1492 − 0.59 ± 0.03 − Kessane 1530 − − 0.65 ± 0.29 Liguloxide 1536 − − 0.02 ± 0.03 Elemol 1549 − − 0.02 ± 0.03 Elemol 1549 − − 0.02 ± 0.03 Elemol 1549 − − 0.02 ± 0.03 E-Nerolidol 1556 t − − 0.09 ± 0.04 E-Nerolidol 1556 t − − 0.02 ± 0.04 0.02 ± 0.			0.68 ± 0.04	_	_
Oxygenated sequiterpenes 6,21 48,27 21.26 10.11-epoxy-Calamenene 1492 - 0.59±0.03 - 10.11-epoxy-Calamenene 1530 - - 0.65±0.29 Liguloxide 1536 - - 0.82±0.37 dis-Sesquisabinene hydrate 1556 t - 0.09±0.04 E-Nerolidol 1565 t - 0.09±0.04 E-Nerolidol 1565 t - 0.09±0.04 E-Nerolidol 1586 t - - - Cermacrene-04-01 1577 t - - 122 202 202 13 0.53±0.23 22 20 0.06±0.03 0.00±0.03			-	_	0.30 ± 0.06
10,11-poxy-Calamenen			C 21	40.27	
Sesane		4.400			
Liguloxide 1536 -					
Elemol 1549 - - - cis-Sesquisabinen hydrate 1556 t - - 1,000 ± 0.04 F-F-Nerolidol 1565 t - - - 1,000 ± 0.04 F-F-Nerolidol 1565 t - <					
cis-Seguisabinene hydrate 1556 t — — 0.09 ± 0.04 E-Nerolidol 1565 t — — 0.09 ± 0.04 E-Nerolidol 1577 t — — 157 Spathulenol 1581 0.62 ± 0.02 41.46 ± 3.04 0.53 ± 0.23 2.20 2.00			-	-	
Liguloxide isomer 1558 F.			-	-	
E-Nerolidol 1565 t - t Germacrne-o-d-ol 1577 t - t Spathulenol 1581 0.62 ± 0.02 41.46 ± 3.04 0.53 ± 0.23 Caryophyllene oxide 1586 1.63 ± 0.56 - 0.06 ± 0.03 F-Copan-4-x-ol 1590 - - 0.06 ± 0.03 Viridilitorl 1595 - 0.13 ± 0.02 t Cedrol 1600 0.27 ± 0.03 - - Guaiol 1601 - 0.76 ± 0.06 - Ledol 1604 - 0.76 ± 0.06 - Spathulenol isomer 1610 0.49 ± 0.06 - - Humulene epoxide 1611 0.49 ± 0.06 - - Zingberenol 1625 - - 0.02 ± 0.01 1-epi-Cubernol 1630 - - 0.02 ± 0.01 1-epi-Cubernol 1630 - - 0.95 ± 0.15 Tau-Cation 1634 - - <td></td> <td></td> <td>t</td> <td>-</td> <td></td>			t	-	
Germacrene-o4-oll 15.77 t - t Cay Day Day Day Day Day Day Day Day Day D		1558	-	-	0.09 ± 0.04
Spathulenol 1581 0.62 ± 0.02 41.46 ± 3.04 0.53 ± 0.23 Caryophyllene oxide 1586 1.63 ± 0.56 - 0.06 ± 0.03 β-Copaen-4-x-ol 1590 - 0.13 ± 0.02 t Viridiflorol 1595 - 0.13 ± 0.02 t Cedrol 1600 0.27 ± 0.03 - 0.22 ± 0.10 Guaiol 1601 - 0.76 ± 0.06 - Spathulenol isomer 1610 - 1.08 ± 0.19 - Phumulene poxide 1611 1.26 ± 0.26 - - Zingiberenol 1625 - - 0.02 ± 0.01 I-epi-Cubersonl 1630 - - 0.02 ± 0.01 Isospathulenol 1634 - - 0.02 ± 0.01 Izury-Eudesmol <td< td=""><td>E-Nerolidol</td><td>1565</td><td>t</td><td>-</td><td>_</td></td<>	E-Nerolidol	1565	t	-	_
Caryophyllene oxide 1586 1.63 ± 0.56 - 0.29 ± 0.04 β-Copan-4-α-ol 1590 - 0.06 ± 0.03 Viridiflorol 1595 - 0.13 ± 0.02 t Cedrol 1600 0.27 ± 0.03 - - 0.22 ± 0.10 Guaiol 1601 - 0.76 ± 0.06 - - Spathulenol isomer 1610 - 1.08 ± 0.19 - - Humulene epoxide 1611 0.49 ± 0.06 - - - Lingiberenol 1611 1.26 ± 0.26 - - - 0.02 ± 0.01 Leepi-Cubersol 1630 - - 0.02 ± 0.01 - - 0.02 ± 0.01 - - 0.02 ± 0.01 - - - 0.02 ± 0.01 - - - - 0.02 ± 0.01 - - - - - - - - - - - - - - - - - - <t< td=""><td>Germacrene-D-4-ol</td><td>1577</td><td>t</td><td>-</td><td>t</td></t<>	Germacrene-D-4-ol	1577	t	-	t
i	Spathulenol	1581	0.62 ± 0.02	41.46 ± 3.04	0.53 ± 0.23
i	Caryophyllene oxide	1586	1.63 ± 0.56	_	0.29 ± 0.04
Viridiflorol 1595 - 0.13 ± 0.02 t Cedrol 1600 0.27 ± 0.03 - - 2 Guaiol 1601 - 0.76 ± 0.06 - 222 ± 0.10 Ledol 1604 - 0.76 ± 0.06 - Spathulenol isomer 1611 0.49 ± 0.06 - - Humulene epoxide 1611 0.49 ± 0.06 - - Lingiberenol 1611 1.26 ± 0.26 - - - 10-epi-γ-Eudesmol 1630 - - 0.02 ± 0.01 - - 0.02 ± 0.01 1-epi-Cubenol 1630 - - - 0.02 ± 0.01 - - - 0.02 ± 0.01 1-epi-Cubenol 1633 - <		1590	_	_	
Cedrol 1600 0.27 ± 0.03 - - - - - - - - - 0.22 ± 0.10 Ledol -			_	0.13 ± 0.02	
Guaiol 1601 - 0.76 ± 0.06 - Ledol 1604 - 0.76 ± 0.06 - Spathulenol isomer 1610 - 1.08 ± 0.19 - Humulene epoxide 1611 0.49 ± 0.06 - - 10-epi-γ-Eudesmol 1625 - - 0.02 ± 0.01 1-epi-Cubenol 1630 - - 0.02 ± 0.01 Isospathulenol 1634 - - 0.02 ± 0.01 Isospathulenol 1635 - - 0.02 ± 0.01 Isospathulenol 1634 - - 0.02 ± 0.01 Arychylla-4.8-dien-5-ol 1644 - - 0.02 ± 0.02 Arychylla-4.8-dien-5-ol 1644 - - 0.03 ± 0.03 β-Eudesmol 1655 - </td <td></td> <td></td> <td>0.27 ± 0.03</td> <td></td> <td></td>			0.27 ± 0.03		
Ledol 1604 - 0.76 ± 0.06 - Spathulenol isomer 1610 - 1.08 ± 0.19 - Humulene epoxide 1611 0.49 ± 0.06 - - Zingiberenol 1611 1.26 ± 0.26 - - 0.02 ± 0.01 11-epi-Cubenol 1630 - - 0.02 ± 0.01 1 Isospathulenol 1634 - 1.39 ± 0.30 - 0.02 ± 0.01 Isospathulenol 1634 - - 0.00 ± 0.01 1 1 0.02 ± 0.01 1 1 0.02 ± 0.01 1 1 0.02 ± 0.01 1 1 0.02 ± 0.01 1 0.02 ± 0.01 1 0.02 ± 0.01 1 0.02 ± 0.01 1 1 0.02 ± 0.01 1 0.02 ± 0.01 1 0.03 ± 0.03 1 1 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 0.03 ± 0.03 <t< td=""><td></td><td></td><td></td><td>_</td><td></td></t<>				_	
Spathulenol isomer 1610 - 1.08 ± 0.19 -				0.76 ± 0.06	
Humulene epoxide 1611 0.49 ± 0.06 - - Zingiberenol 1611 1.26 ± 0.26 - - $10-epi-γ-Eudesmol$ 1630 - - 0.02 ± 0.01 1-epi-Cubenol 1630 - - 0.02 ± 0.01 Isospathulenol 1633 - - 0.99 ± 0.30 - γ-Eudesmol 1635 - - 0.99 ± 0.15 0.99 ± 0.15 tau-Catdinol 1643 1.27 ± 0.10 - 0.99 ± 0.15 0.99 ± 0.15 tau-Gatinol 1644 - - 0.09 ± 0.15 0.09 ± 0.02 0.09 ± 0.02 0.00 ± 0.02					_
zingberenol 1611 1,26 ± 0,26 - - 10-epiγ-Eubenol 1625 - - 0.02 ± 0.01 1sospathulenol 1634 - 1,39 ± 0.30 - γ-Eudesmol 1634 - 1,39 ± 0.30 - γ-Eudesmol 1635 - - 0.95 ± 0.15 tau-Cadimol 1640 - - 0.95 ± 0.15 tau-Cadimol 1643 1,27 ± 0.10 - t allo-Aromadendrene epoxide 1644 - - - allo-Aromadendrene epoxide 1645 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1655 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1655 - - 0.03 ± 0.01 α-Eduesmol 1655 - - 0.03 ± 0.01 α-Eudesmol 1658 0.29 ± 0.04 - - Selin-11-e-4-α-ol 1667 - - 0.03 ± 0.03 Intermedol 1667 -					-
10-epi-γ-Eudesmol 1625 - - 0.02 ± 0.01 1-epi-Cubenol 1630 - - 0.02 ± 0.01 Isospathulenol 1634 - 1.39 ± 0.30 - γ-Eudesmol 1635 - - 0.95 ± 0.15 Caryophylla-4,8-dien-5-ol 1640 - - 0.95 ± 0.15 tau-Gatinol 1643 1.27 ± 0.10 - t allo-Aromadendrene epoxide 1644 - - - tau-Murolol 1645 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1655 - - 0.03 ± 0.01 α-Edudesmol 1655 - - 0.03 ± 0.01 α-Edudesmol 1655 - - 0.00 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - 0.03 ± 0.01 α-Eudesmol 1667 - - 0.03 ± 0.01 - - 0.03 ± 0.01 - - 0.03 ± 0.01 - 0.03 ± 0.01 -					-
1-epi-Cubenol 1630 - - 0.02 ± 0.01 Isospathulenol 1634 - 1.39 ± 0.30 - Y-Y-Eydesmol - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - 5.64 ± 1.38 - - - 5.64 ± 1.38 - - - - - - 1.65 -					_
Isospathulenol 1634 - 1.39 ± 0.30 - γ-Eudesmol 1635 - - 5.64 ± 1.38 Caryophylla-4.8-dien-5-ol 1640 - - 0.95 ± 0.15 tau-Cadinol 1643 1.27 ± 0.10 - t allo-Aromadendrene epoxide 1644 - - - tau-Muurolol 1645 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1650 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.03 ± 0.01 α-Eudesmol 1658 0.29 ± 0.04 - - α-Cadinol 1658 0.29 ± 0.04 - - Selin-11-en-4-α-ol 1661 - - 0.03 ± 0.03 Intermedeol 1667 - - 0.03 ± 0.03 Intermedeol 1667 - - 0.12 ± 0.02 epi-β-Bisabolol 1674 0.39 ± 0.17 - - Isobicyclogermacrenal 1734 - <td></td> <td></td> <td></td> <td>-</td> <td></td>				-	
γ-Eudesmol 1635 0.5.64 ± 1.38 Caryophylla-4,8-dien-5-ol			-		0.02 ± 0.01
Caryophylla-4,8-dien-5-ol 1640 - - 0.95 ± 0.15 tau-Cadinol 1643 1.27 ± 0.10 - t allo-Aromadendrene epoxide 1644 - - - tau-Muurolol 1645 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1650 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.05 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - 0.05 ± 0.02 α-Cadinol 1661 - - 0.03 ± 0.03 0.03 0.03 Intermedeol 1667 - - 0.03 ± 0.01 0.03 0.03 0.03 1.03 0.12 ± 0.02 0.03 0.02		1634	-	1.39 ± 0.30	_
tau-Cadinol 1643 1.27 ± 0.10 - t allo-Aromadendrene epoxide 1644 - - - tau-Muurolol 1645 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1650 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.05 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - 0.05 ± 0.02 Selin-11-en-4-α-ol 1661 - - 0.03 ± 0.03 0.03 Intermedeol 1667 - - 0.03 ± 0.03 0.03 0.03 Caryophyllenol 1672 - - - 0.12 ± 0.02 epi-β-Bisabolol 1674 0.39 ± 0.17 - - - 1.02 ± 0.02 -		1635	-	-	5.64 ± 1.38
allo-Aromadendrene epoxide 1644 - - - tau -Muurolol 1645 - 0.48 ± 0.13 0.89 ± 0.42 β -Eudesmol 1650 - - 0.03 ± 0.01 α -Eudesmol 1655 - - 0.05 ± 0.02 α -Cadinol 1658 0.29 ± 0.04 - - 0.03 ± 0.03 Selin-11-en-4- α -ol 1661 - - 0.03 ± 0.03 1 Intermedeol 1667 - - 0.03 ± 0.03 1 Caryophyllenol 1672 - - 0.12 ± 0.02 2 9.59 ± 0.89 Caryophyllenol 1674 0.39 ± 0.17 - - 0.12 ± 0.02 2 -	Caryophylla-4,8-dien-5-ol	1640	_	-	0.95 ± 0.15
tau-Muurolol 1645 - 0.48 ± 0.13 0.89 ± 0.42 β-Eudesmol 1650 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.05 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - Selin-11-en-4α-σl 1661 - - 0.03 ± 0.03 Intermedol 1667 - - 0.12 ± 0.02 Caryophyllenol 1672 - - 0.12 ± 0.02 epi-β-Bisabolol 1674 0.39 ± 0.17 - - - epi-α-Bisabolol 1687 t -	tau-Cadinol	1643	$\boldsymbol{1.27 \pm 0.10}$	-	t
β-Eudesmol 1650 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.05 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - 0.05 ± 0.02 α-Cadinol 1661 - - 0.03 ± 0.03 10.03 10.03 10.03 10.03 10.03 10.02 - 0.12 ± 0.02 9.59 ± 0.89 0.02 - 0.12 ± 0.02 9.59 ± 0.89 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.02 0.03	allo-Aromadendrene epoxide	1644	_	-	_
β-Eudesmol 1650 - - 0.03 ± 0.01 α-Eudesmol 1655 - - 0.05 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - Selin-11-en-4-α-ol 1661 - - 0.03 ± 0.03 Intermedeol 1667 - - 9.59 ± 0.89 Caryophyllenol 1672 - - 0.12 ± 0.02 epi-β-Bisabolol 1674 0.39 ± 0.17 - - - epi-β-Bisabolol 1687 t - - - - Isobicyclogermacrenal 1734 - 1.92 ± 0.29 - - Oxygenated diterpenes 1 1.05 - t t Phytol 1945 0.96 ± 0.32 - t t Phytol siomer 1974 0.09 ± 0.02 - t t 1-Octene 793 - t 0.07 ± 0.02 1-Octene 793 - - t	tau-Muurolol	1645	_	0.48 ± 0.13	$\boldsymbol{0.89 \pm 0.42}$
α-Eudesmol 1655 - - 0.05 ± 0.02 α-Cadinol 1658 0.29 ± 0.04 - - Selin-11-en-4-α-ol 1661 - - 0.03 ± 0.03 Intermedeol 1667 - - 9.59 ± 0.89 Caryophyllenol 1672 - - 0.12 ± 0.02 epi -β-Bisabolol 1674 0.39 ± 0.17 - - - Isobicyclogermacrenal 1734 - 1.92 ± 0.29 - - Oxygenated diterpenes 1.05 - t t -	β-Eudesmol	1650	_	_	
α-Cadinol 1658 0.29 ± 0.04 - - Selin-11-en-4-α-ol 1661 - - 0.03 ± 0.03 Intermedeol 1667 - - 9.59 ± 0.89 Caryophyllenol 1672 - - 0.12 ± 0.02 epi-β-Bisabolol 1674 0.39 ± 0.17 - - - epi-α-Bisabolol 1687 t - - - Isobicyclogermacrenal 1734 - 1.92 ± 0.29 - - Oxygenated diterpenes 1.05 - t t -			_	_	
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Total identified 96.22 95.40 96.84	Total identified		06.22	05.40	06.94

Compounds listed in order of elution in the HP-1 column. T, traces (<0.04% *L. camara* and *E. camaldulensis* and <0.01% in *E. africanus*). RI, retention index relative to C_8-C_{32} *n*-alkanes on the HP-1 column. Peak area percentages are calculated in GC on apolar HP-1 column. Values are means \pm standard error.

 Table 2

 Effects of essential oils from Lantana camara, Eucalyptus camaldulensis and Eriocephalus africanus on Amaranthus hybridus and Portulaca oleracea seeds germination.

Treatment (μl/ml)	Lantana camara	Eucalyptus camaldulensis	Eriocephalus africanus				
Amaranthus hybridus germinat	Amaranthus hybridus germination (%)						
0 (Control)	87.0 ± 6.4 a	$87.0 \pm 6.4 \text{ a}$	$87.0 \pm 6.4~a$				
0.125	$6.0\pm2.9~\mathrm{b}$	$0.0 \pm 0.0 \; \mathrm{b}$	$0.0\pm0.0~\mathrm{b}$				
0.250	$12.0 \pm 6.0 \ b$	$0.0 \pm 0.0 \; b$	$1.0\pm1.0~b$				
0.5	$5.0\pm2.7~b$	$0.0 \pm 0.0 \; b$	$1.0\pm1.0~b$				
1	$3.0\pm2.0\;b$	$0.0\pm0.0\;b$	$0.0 \pm 0.0 \ b$				
Portulaca oleracea germination (%)							
0 (Control)	$100.0 \pm 0.0 \; a$	100.0 ± 0.0 a	$100.0 \pm 0.0 \; a$				
0.125	$95.0 \pm 2.7 \text{ a}$	$0.0 \pm 0.0 \; b$	$94.0 \pm 3.7 \ a$				
0.250	$92.0 \pm 3.0 \ a$	$0.0 \pm 0.0 \; b$	$96.0\pm1.9~a$				
0.5	94.0 ± 1.9 a	$0.0 \pm 0.0 \; b$	77.0 ± 7.7 b				
1	$97.0\pm1.2~\text{a}$	$0.0 \pm 0.0 \ b$	$76.0\pm10.0\;b$				

Values are means \pm standard error of five replicates of 20 seeds each after 14 days of incubation. Within each species, different letters in the same column indicate that means are different at the 95% level of probability (Tukey's multiple-range test, HSD).

reduced, being practically 0 at all the concentrations assayed, without differences between concentrations. In *P. oleracea*, however, the seedling length was reduced at all the concentrations applied (Fig. 2), and there were significant differences between the control and the lower concentrations, which reduced germination 34.23%, 39.78% and 41.51%, respectively and also there were significant differences between the highest concentration and the others. The highest concentration caused a decrease of 50.45% in *P. oleracea* seedling length.

A continuous decrease of the seedling growth rate was observed (Figs. 1 and 2).

4. Discussion

Essential oils from different aromatic plants belonging to Lamiaceae, Compositae, Myrtaceae and Verbenaceae families have been reported to have allelopathic properties (Dudai et al., 1999; Angelini et al., 2003). The allelopathic effect of the essential oils is related to the essential oil composition and the species on which they are applied. In this sense, our results corroborate that the great differences in the essential oils composition of *L. camara*, *E. camaldulensis* and *E. africanus* produced a strong or more selective phytotoxic effect against *A. hybridus* or *P. oleracea* germination or seedling growth.

According to other authors (Scrivanti et al., 2003; López et al., 2009), the essential oils, rich in oxygenated compounds, were more active than essential oils with high percentages of hydrocarbon compounds.

The essential oil composition of *L. camara* changes depending on the geographical origin. *L. camara* growing in Spain is an ornamental plant with an essential oil rich in sesquiterpene compounds, mainly hydrocarbonated and devoid of monoterpene compounds. In India *L. camara* has become an obnoxious weed. Its essential oil contains, besides sesquiterpene hydrocarbons, oxygenated monoterpenes, 1,8-cineole and linalool with percentages near 1% and monoterpene hydrocarbons

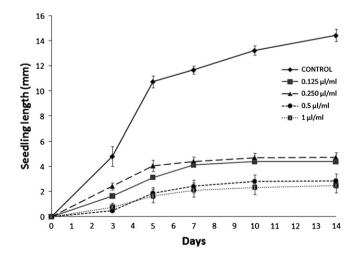


Fig. 1. Seedling length (mm) (mean \pm SE) of *P. oleracea* control or treated with essential oil from *E. africanus* at concentrations of 0.125 μ l/ml, 0.25 μ l/ml and 1 μ l/ml measured for 14 days.

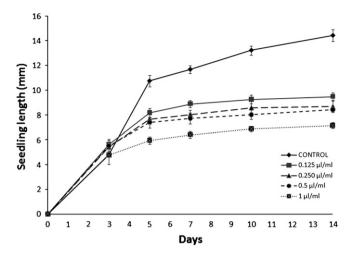


Fig. 2. Seedling length (mm) (mean \pm SE) of *P. oleracea* control or treated with essential oil from *L. camara* at concentrations of 0.125 μl/ml, 0.25 μl/ml and 1 μl/ml measured for 14 days.

such as sabinene or myrcene that reach 2.2% and 1.2%, respectively. It also contains davanone, an oxygenated sesquiterpene in large amounts (7.3%) (Rana et al., 2005). On the other hand aqueous extracts of *L. camara* had been widely described in India as allelopathic against many crops and weeds (Bansal, 1998). In previous assays (Verdeguer et al., 2007) we found that the aqueous extract of *L. camara* growing in Spain was not as effective against germination or seedling growth of *A. hybridus* and *P. oleracea* as its essential oil. Our results suggest that its essential oil could be used as a potential allelopathic substance.

Several authors suggested that monoterpene compounds are responsible for germination inhibition (Dudai et al., 2004; Armirante et al., 2006.). The minor effectiveness of *L. camara* compared with *E. camaldulensis* and *E. africanus* essential oils could be explained by the absence of a monoterpene fraction.

Essential oils from *Eucalyptus* species had shown strong inhibitory effects on germination of seeds of many crops and weeds (Sing et al., 2002; Azizi and Fuji, 2006). The essential oil composition of *E. camaldulensis* from different origins had been reported. Two groups of *E. camaldulensis* essential oils can be distinguished: those that contain 1,8-cineole as the main compound, which includes *E. camaldulensis* from Mali, Mozambique, Nigeria, Egypt and Iran (Chalchat et al., 2000; Pagula et al., 2000; Oyedeji et al., 2000; Maximous, 2004; Sefidkon et al., 2006) and those that contain spathulenol, *p*-cymene and cryptone as main compounds and small quantities of 1,8-cineol, like the results we obtained, which are similar to *E. camaldulensis* from south Florida, Jerusalem and Greece (Pappas and Sheppard-Hanger, 2000; Chalchat et al., 2001; Tsiri et al., 2003). Both essential oil compositions were reported from *E. camaldulensis* clones growing in Australia (Dunlop et al., 2000). Our results suggest according to other authors (Angelini et al., 2003) that 1,8-cineol is not the principal responsible for the allelopathic effect from *Eucalyptus* sp. essential oil. The essential oil from *E. camaldulensis* assayed contained spathulenol as the main compound with percentage around 40%, whereas 1,8-cineole only reached 1.92 \pm 0.32 of the total oil.

To conclude, it is interesting to note the results obtained with *E. africanus* essential oil: with the oxygenated monoterpene artemisia ketone as the main compound (56.46 ± 1.99); it was more active than *L. camara*, showing great selectivity against *A. hybridus*.

Further studies under field conditions are necessary to evaluate the possible use of these essential oils for their allelopathic activity.

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