# Progress in Essential Oils

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## *Eucalyptus globulus* Oil

A Moroccan oil of *Eucalyptus globulus* L. was examined for its major constituents (Lahlou et al. 2000). The components identified were as follows:

β-pinene (0.68%)
α-pinene (12.97%)
1,8-cineole (70.67%)
borneol (0.36%)
carveol* (1.94%)
α-terpinyl acetate (3.68%)
aromadendrene (1.96%)
globulol (3.76%)

*correct isomer not identified

An oil of *E. globulus* produced from leaves harvested from trees in Argentina was analyzed for its main constituents by Larrán et al. (2001). The main components found were as follows:

α-pinene (9.3%)
1,8-cineole (64.5%)
α-terpineol (2.6%)
epi-globulol (1.1%)
globulol (5.1%)

An oil of *E. globulus* produced in the laboratory from leaves collected in Algeria was analyzed by Benayache et al. (2001). The composition of this oil was reported to be as follows:

α-pinene (8.8%)
camphene (0.1%)
sabinene (< 0.1%)
myrcene (0.2%)
limonene (2.7%)
1,8-cineole (71.3%)
pinocarvone (0.7%)
aromadendrene (1.5%)
terpinen-4-ol (0.3%)
allo-aromadendrene (0.4%)
*trans*-pinocarveol (3.3%)
α-terpineol (2.7%)
epi-globulol (0.4%)
globulol (1.6%)

Mandal et al. (2001) analyzed oils produced from the leaves of *E. globulus* obtained from trees growing in four different geoclimatic zones in India (Bangalore, Nagpur, Gwalior and Nilgiri). A summary of the analytical results is presented in T-1.

Farah et al. (2002) examined the composition of oils produced from various eucalyptus cultivars grown in Morocco, among which was an oil of *E. globulus*. This oil was found to contain the following constituents:

α-pinene (7.57%)
camphene (0.51%)
β-pinene (0.10%)
α-phellandrene (0.34%)
p-cymene (0.60%)
1,8-cineole (74.18%)
γ-terpinene (0.18%)
linalool (0.10%)
*trans*-pinocarveol (0.54%)
pinocarvone (0.05%)
borneol (0.30%)
terpinen-4-ol (0.24%)
α-terpineol (1.80%)
myrtenal (0.05%)
*trans*-carveol (0.08%)
nerol (0.21%)
*cis*-carveol (0.10%)
carvone (0.05%)
piperitone (0.05%)
α-terpinyl acetate (1.20%)
β-caryophyllene (0.03%)

**Comparative percentage composition of *Eucalyptus globulus* oil produced from four regions of India** **T-1**

| Compound | Bangalore | Nagpur | Gwalior | Nilgiri |
|---|---|---|---|---|
| α-pinene | 11.0 | 24.3 | 15.3 | 29.9 |
| camphene | 0.7 | 0.9 | 0.6 | 0.3 |
| β-pinene | 5.9 | 8.1 | 10.9 | 0.1 |
| sabinene | 1.1 | 0.6 | 1.9 | 0.7 |
| limonene | 1.0 | 0.8 | 5.0 | 0.1 |
| 1,8-cineole | 53.2 | 32.3 | 28.4 | 45.2 |
| γ-terpinene | 0.8 | 2.5 | 1.0 | 0.7 |
| p-cymene | 7.0 | 4.9 | 4.5 | 0.4 |
| terpinolene | 0.2 | 0.2 | 0.2 | 0.1 |
| pinocarvone | 1.1 | 1.3 | 0.6 | 2.2 |
| terpinen-4-ol | 1.0 | 1.3 | 0.8 | 0.5 |
| β-caryophyllene | 0.1 | 0.1 | < 0.1 | 0.6 |
| aromadendrene | 0.7 | 2.2 | 2.1 | 0.1 |
| allo-aromadendrene | 0.9 | 2.7 | 0.6 | 0.1 |
| neral | 1.1 | 1.9 | 2.7 | 2.2 |
| α-terpineol | 3.6 | 3.6 | 2.2 | 2.2 |
| carvone | 0.3 | 0.3 | 0.3 | 0.4 |
| caryophyllene oxide | 0.1 | 0.5 | 1.1 | 0.1 |
| globulol | 0.9 | 5.0 | 4.6 | 0.3 |



aromadendrene (0.42%)
allo-aromadendrene (0.34%)
α-selinene (0.20%)
(E)-nerolidol (0.25%)
ledol (0.13%)
spathulenol (1.50%)
globulol (0.70%)
guaiol (0.21%)

γ-eudesmol (0.08%)
β-eudesmol (0.03%)
α-eudesmol (0.09%)

In addition, trace amounts (< 0.05%) of α-thujene, α-fenchol, p-cymen-8-ol, myrtenol, geraniol and carvacrol also were found in this same oil.

Singh and Naqvi (2002) reported that the 1,8-cineole content of the oil of *E. globulus* found growing in the Kumoun region (India) was 55.5%.

Cimanga et al. (2002, 2002) screened a number of leaf oils produced from *Eucalyptus* species growing in the Democratic Republic of Congo for their antimicrobial properties. The oil composition of *E. globulus* was reported to be as follows:

α-pinene (9.3%)
camphene (23.1%)
β-pinene (2.7%)
limonene (5.1%)
1,8-cineole (44.3%)
p-cymene (1.6%)
linalool (0.3%)
aromadendrene (1.3%)
terpinen-4-ol (0.2%)
cryptone (1.3%)
α-terpineol (0.3%)

**Comparative percentage composition of eucalyptus oils of Spanish and Chinese origins** **T-2**

| Compound | Spanish oil | Chinese oil |
|---|---|---|
| isovaleraldehyde | 0.11 | – |
| α-pinene | 17.35 | 6.01 |
| α-fenchene | 0.02 | – |
| camphene | 0.06 | 0.03 |
| β-pinene | 0.53 | 0.80 |
| verbenene | 0.03 | – |
| myrcene | 0.33 | 0.54 |
| α-phellandrene | 0.23 | 0.24 |
| α-terpinene | – | 0.04 |
| limonene | 4.65 | 7.59 |
| β-phellandrene | 0.13 | 0.16 |
| 1,8-cineole | 61.76 | 80.46 |
| (Z)-β-ocimene | 0.06 | 0.09 |
| γ-terpinene | 0.59 | 0.70 |
| (E)-β-ocimene | 0.07 | 0.10 |
| p-cymene | 2.47 | 2.17 |
| terpinolene | 0.09 | 0.10 |
| isoamyl isobutyrate | 0.07 | 0.02 |
| p-cymenene | 0.07 | – |
| δ-elemene | 0.05 | – |
| α-copaene | 0.03 | – |
| camphor† | – | 0.27 |
| α-gurjunene | 0.26 | – |
| linalool | 0.07 | 0.09 |
| pinocarvone | 0.18 | – |
| β-guaiene* | 0.14 | – |
| β-caryophyllene | 0.07 | 0.04 |
| terpinen-4-ol | 0.48 | 0.10 |
| aromadendrene | 2.63 | – |
| allo-aromadendrene | 0.51 | – |
| *trans*-pinocarveol | 1.00 | 0.13 |
| α-terpinyl acetate | 1.36 | – |
| α-terpineol | 1.04 | 0.13 |
| borneol | 0.09 | 0.04 |
| geranyl acetate | 0.19 | – |
| *trans*-p-mentha-1(7),8-dien-2-ol | 0.17 | – |
| *trans*-carveol | 0.05 | – |
| geraniol + p-cymen-8-ol | 0.18 | – |
| *cis*-p-mentha-1(7),8-dien-2-ol | 0.10 | – |
| globulol | 0.12 | – |
| epi-globulol | 0..36 | – |
| β-eudesmol | 0.09 | – |

*correct isomer not identified; †tentative identification

α-terpinyl acetate (1.2%)
citronellol (0.1%)
geraniol (0.2%)
globulol (7.3%)

Kubeczka and Formacek (2002) used a combination of capillary GC and $^{13}$C-NMR spectroscopy to compare the compositions of eucalyptus oil (ex *E. globulus*) of Spanish and Chinese origins.

The results of this study can be seen summarized in T-2. Based on the composition of the Chinese oil, it would appear that this is not a crude oil but one that has been fractionally distilled to increase the 1,8-cineole content.

The enantiomeric purity of selected constituents of eucalyptus oil and the leaves of living eucalyptus trees (ex *E. globulus*) was determined by Kreck et al. (2002) using stir bar sorptive extraction coupled with multi-dimensional chiral GC coupled with GC/MS. The results of this study can be seen in T-3.

Viturro et al. (2003) compared the oil composition of leaf and leaf/stem oils of *Eucalyptus globulus* ssp. *bicostata* of Argentinian origin. The results of this study can be seen in T-4.

Eleven lab-distilled oils of *E. globulus* obtained from Australia were the subject of analysis by Dunlop et al. (2003). They found that the oils contained a range of the following constituents:

- α-pinene (2.3–14.8%)
- limonene (0.2–5.1%)
- 1,8-cineole (39.3–52.7%)
- p-cymene (0.2–1.1%)
- pinocarvone (0.3–4.2%)
- β-elemene (0–0.7%)
- β-caryophyllene (0–5.5%)
- aromadendrene (8.1–12.8%)
- allo-aromadendrene (1.6–2.9%)
- *trans*-pinocarveol (0.7–6.0%)
- δ-terpineol (0.1–0.3%)
- α-terpineol (0.1–6.2%)
- *trans*-p-mentha-1(7),8-dien-2-ol (0.1–1.0%)
- *cis*-p-mentha-1(7),8-dien-2-ol (0.2–1.2%)
- epi-globulol (0.7–1.0%)
- globulol (3.0–4.9%)
- viridiflorol (0.8–1.2%)
- spathulenol (0.1–0.8%)
- γ-eudesmol (0–0.2%)
- α-eudesmol (0.1–0.6%)
- β-eudesmol (0.2–0.8%)
- torquatone (0.1–2.7%)

A refined commercial oil of *E. globulus* was screened against human head lice (*Pediculus humanus capitis*) by Yang et al. (2004). The main constituents of this oil were found to be:

- α-pinene (2.2%)
- β-pinene (0.6%)
- myrcene (0.6%)
- α-phellandrene (0.5%)
- p-cymene (1.5%)
- 1,8-cineole (90.0%)
- γ-terpinene (0.7%)
- *trans*-pinocarveol (0.4%)
- α-terpineol (1.7%)

The authors found that 1,8-cineole, α-terpineol and *trans*-pinocarveol merited further study as a potential pediculicide against human head lice.

An oil produced from *E. globulus* fruits was found to be very different from the leaf oil from the same species (Pereira et al. 2004), as it was rich in α-phellandrene (17.2%), 1,8-cineole (11.7%) and aromadendrene (25.1%).

A commercial oil of *E. globulus*, produced in Yunnan, China, was the subject of analysis by Milchard et al. (2004). The

**Enantiomeric purity (%) of selected components of eucalyptus oil and living eucalyptus trees** **T-3**

| Compound | Eucalyptus oil | Eucalyptus plants |
|---|---|---|
| (1R,5R)-(+)-α-pinene | 93–99 | 94–99 |
| (1S,5S)-(-)-β-pinene | 59–65 | 50–57 |
| (4R)-(+)-α-phellandrene | 76–83 | 76–89 |
| (4R)-(+)-limonene | 64–72 | – |
| (3R)-(-)-linalool | 60–70 | 65–71 |
| (1S,4S)-(+)-terpinen-4-ol | 53–58 | 67–73 |
| (1R,4R)-(+)-α-terpineol | 66–72 | 67–71 |

constituents identified in this oil were as follows:

α-pinene (4.0%)
β-pinene (0.7%)
myrcene (0.7%)
α-phellandrene (0.4%)
p-cymene (2.1%)
1,8-cineole (83.1%)
limonene (5.4%)
γ-terpinene (1.1%)
terpinolene (0.2%)
terpinen-4-ol (0.3%)
α-terpineol (0.8%)

**Comparative percentage composition of the oils of *Eucalyptus globulus* ssp. *bicostata*** **T-4**

| Compound | Leaf oil | Leaf/stem oil |
|---|---|---|
| isovaleraldehyde | 0.8 | 0.8 |
| α-fenchene | t | t |
| α-pinene | 4.1 | 4.1 |
| myrcene | 0.2 | 0.2 |
| α-phellandrene | 0.4 | 0.5 |
| limonene | 0.6 | 0.5 |
| 1,8-cineole | 90.7 | 88.0 |
| (Z)-β-ocimene | – | 0.1 |
| γ-terpinene | 0.1 | 0.2 |
| terpinolene | 0.2 | 0.2 |
| linalool | t | 0.1 |
| α-phellandren-8-ol | 0.1 | 0.2 |
| terpinen-4-ol | 0.4 | 0.5 |
| α-terpineol | 1.6 | 3.2 |
| citronellol | t | t |
| *cis*-carveol | t | 0.1 |
| geraniol | 0.1 | 0.2 |
| geranial | 0.1 | 0.2 |
| methyl geranate | – | 0.2 |
| β-caryophyllene | – | 0.2 |
| β-gurjunene | – | t |
| aromadendrene | 0.1 | t |
| α-humulene | – | 0.1 |
| allo-aromadendrene | t | – |
| viridiflorene | t | – |
| globulol | 0.2 | 0.2 |

t = trace (< 0.1%)


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## Citronella Oil

Lemos et al. (1992) examined the antimicrobial activity of the oils of a few Brazilian-grown aromatic plants. Among the oils examined was citronella (ex *Cymbopogon nardus*) oil produced from plants grown in Fortaleza, Brazil. The composition of the oil that was screened was as follows:

sabinene (1.1%)
myrcene (0.5%)
limonene (3.2%)
linalool (1.4%)
isopulegol (2.7%)
citronellal (34.6%)
citronellol (10.6%)
neral (28.6%)
geranial (1.4%)
eugenol (1.0%)
geranyl acetate (4.6%)
β-elemene (0.5%)
germacrene D (0.5%)
δ-cadinene (0.4%)
elemol (3.7%)
elemicin (7.3%)
α-cadinol (1.8%)

As part of an antimicrobial screening program, Aggarwal et al. (2000) determined that the major constituents of Java citronella oil produced in India were:

limonene (2.10%)
citronellal (31.50%)
linalool (1.00%)
linalyl acetate (1.04%)
β-caryophyllene (2.90%)
citronellyl acetate (3.25%)
geranyl formate (5.20%)
citronellol (15.90%)
geraniol (52.30%)
elemol (5.06%)

Hifnawy et al. (2001) determined that an oil of *C. nardus* contained the following major constituents:

methylbutenol* (0.2%)
myrcene (4.5%)
6-methyl-5-hepten-2-one (1.0%)
*cis*-linalool oxide furanoid (0.1%)
*cis*-dihydrocarvone (0.2%)
linalool (1.0%)
pulegone (0.5%)
neral (34.5%)
geranial (46.5%)
geranyl acetate (0.7%)
citronellol (0.6%)
geraniol (2.9%)
α-vetivone (0.4%)
β-vetivone (1.1%)

*correct isomer not identified

It should be noted that the previously mentioned oil composition is incorrect for citronella oil. It appears to this reviewer that both the identity of the plants from which the oil was obtained is in error and possibly the characterization of some of the components—particularly the vetivone isomers.

Rout et al. (2001) analyzed the fractions obtained from a hydrodistillation of citronella grass. The fractions were taken every 15 min, except for fraction one and fraction 12, which were taken at 20 min and 40 min, respectively. The authors compared the composition of both the oil fractions and the oil isolated from the distillate water obtained at the same fraction interval time. The components characterized in the oil fractions and the range of composition were as follows:

limonene (0.25–4.36%)
linalool (0.70–1.40%)
isopulegol (0–1.10%)
citronellal (7.0–48.5%)
citronellol (7.9–12.5%)
geraniol (15.3–28.1%)
citronellyl acetate (2.2–3.8%)
eugenol (0.31–0.60%)
geranyl acetate (1.98–6.57%)
β-elemene (4.3–13.0%)
germacrene D (0.90–3.50%)
δ-cadinene (0.70–4.17%)
elemol (2.30–15.40%)
γ-eudesmol (0–2.24%)
α-muurolol (0.26–1.59%)
α-cadinol (0–5.10%)

In contrast, the components isolated from the distillate water fractions and the range of composition were as follows:

6-methyl-5-hepten-2-one (0.13–0.56%)
benzyl alcohol (0.20–0.81%)
linalool (1.29–1.89%)
isopulegol (1.85–3.64%)
citronellal (1.36–10.39%)
citronellol (9.11–10.47%)
geraniol (27.94–40.87%)
2-(2-hydroxy-2-propyl)-5-methylcyclohexanol (7.51–16.54%)
citronellyl acetate (3.02–9.85%)
eugenol (0.65–2.15%)
terpin hydrate (2.32–7.21%)
geranyl acetate (3.30–6.63%)
β-elemene (0.85–5.15%)
germacrene D (0.27–2.36%)
δ-cadinene (0.25–2.48%)
elemol (0.69–7.76%)
γ-eudesmol (0.15–1.02%)
α-muurolol (0.16–0.81%)
α-eudesmol (0.26–2.12%)

The characterizations of 2-(2-hydroxy-2-propyl)-5-methyl-cyclohexanol and terpin hydrate need corroboration if their identifications are to be accepted, because they are not normally found as essential oil constituents or even constituents of the distillation water.

The effect of altitude and plant age on the major components of the oils isolated from Java citronella (*C. winterianus*) grown in various locations in India was the subject of study by Sarma et al. (2001). They found that the highest yield of herbage per hectare and oil content was obtained from plants grown at 60 m (altitude) in Sepahijala (Tripura), whereas the highest content of citronellal (56.7%) was found when plants were grown in Yaongyimsen (Nagaland). The authors found that plantations two and a half years old produced the highest oil yield (1.35%), with the citronellal, citronellol and geraniol contents of 44.0%, 18.9% and 24.9%, respectively. Finally, the authors also found that the ideal time to harvest the plants was 90 days from planting, and the maximum productive length of a plantation was five years.

Koumaglo (2002) determined that citronella oils (*C. nardus*) produced in Togo contained the following major constituents:

citronellal (19–47%)
citronellol (6–13%)
citronellyl acetate (2%)
geraniol (18–41%)
elemol (2.7–7%)

Kubeczka and Formacek (2002) compared the composition of Sri Lankan citronella oil (ex *C. nardus*) and Java citronella oil (ex *C. winterianus*) using capillary

GC and $^{13}$C-NMR as their method of analysis. The comparative compositions can be seen in T-5.

Lorenzo et al. (2002) determined that the enantiomeric distributions of some selected constituents of citronella oil (ex *C. winterianus*) were as follows:

(4R)-(+)-limonene (13.0%):(4S)-(-)-limonene (87.0%)
(3S)-(+)-linalool (38.7%):(3R)-(-)-linalool (61.3%)
(3R)-(+)-citronellal (91.2%):(3S)-(-)-citronellal (8.8%)
(3R)-(+)-citronellol (84.7%):(3S)-(-)-citronellol (15.3%)

Singh et al. (2002) showed that the effect of partial shade on oil produced from citronella oil grown in India as *C. winterianus* was minimal. They found that the major constituents varied only slightly, as can be seen below.

citronellal (40.6–43.6%)
isopulegol (0.1–2.3%)
citronellol (14.1–14.4%)
geraniol (19.7–22.7%)
elemol (3.5–4.1%)
caryophyllene oxide (4.0%)

Narayanan (2003) analyzed an oil of *C. winterianus* (Java citronella) of Indian origin and found that the major components were:

limonene (3.21%)
linalool (0.62%)
citronellal (41.33%)
citronellol (10.46%)
geraniol (21.58%)
citronellyl acetate (2.59%)
geranyl acetate (3.96%)
β-elemene (2.28%)
β-caryophyllene (0.05%)
germacrene D (1.40%)
γ-cadinene (1.02%)
elemol (2.28%)

Narayanan further reported that the main constituents of an oil in which the citronellal had been removed were:

limonene (1.07%)
linalool (1.69%)
citronellal (2.13%)
citronellol (4.82%)
geraniol (42.22%)
geranyl acetate (5.24%)

**Comparative percentage composition of Sri Lankan and Java-type citronella oils** **T-5**

| Compound | Sri Lankan oil | Java-type oil |
|---|---|---|
| tricyclene | 1.52 | – |
| α-pinene | 2.74 | 0.03 |
| camphene | 9.78 | – |
| β-pinene | 0.08 | – |
| sabinene | 0.18 | 0.08 |
| δ-3-carene | 0.12 | – |
| myrcene | 0.87 | 0.13 |
| α-phellandrene | 0.11 | – |
| γ-terpinene† | 0.03 | – |
| limonene | 9.54 | 4.46 |
| β-phellandrene | 0.52 | 0.04 |
| (Z)-β-ocimene | 2.12 | 0.03 |
| (E)-β-ocimene | 1.03 | 0.04 |
| p-cymene | 0.19 | 0.01 |
| terpinolene | 0.64 | 0.08 |
| 6-methyl-5-hepten-2-one | 0.07 | 0.11 |
| *cis*-rose oxide | 0.04 | 0.08 |
| citronellal | 4.07 | 37.79 |
| β-bourbonene | 0.27 | 0.12 |
| linalool | 0.64 | 1.10 |
| iso(iso)pulegol | – | 0.47 |
| isopulegol | 0.04 | 1.38 |
| β-elemene | 0.91 | 1.64 |
| β-caryophyllene | 1.69 | 0.08 |
| neoisopulegol | 0.25 | 0.11 |
| citronellyl acetate | 0.61 | 3.42 |
| neral | 0.15 | 0.32 |
| γ-muurolene | – | 0.16 |
| α-terpineol | 2.65 | 0.07 |
| borneol | 5.63 | – |
| germacrene D | 1.17 | 1.73 |
| α-muurolene | – | 0.45 |
| geranial | 0.45 | 0.52 |
| δ-cadinene | 0.48 | 1.84 |
| geranyl acetate | 2.86 | 4.44 |
| citronellol | 3.70 | 11.11 |
| α-cadinene | – | 0.10 |
| nerol | 0.46 | 0.20 |
| geraniol | 18.28 | 21.63 |
| methyl eugenol | 1.00 | – |
| germacrene D-4-ol | – | 0.26 |
| elemol | 0.98 | 1.83 |
| eugenol | – | 0.89 |
| T-cadinol | 0.30 | 0.37 |
| (E)-methyl isoeugenol | 6.85 | – |
| T-muurolol | 0.15 | 0.21 |
| α-muurolol | 0.04 | 0.05 |
| α-cadinol | 0.44 | 0.60 |

†misidentification, should be α-terpinene

A steam-distilled oil of partially dried citronella grass (*C. nardus*) was analyzed by Mahalwal and Ali (2003). The components found in this oil were:

α-pinene (0.5%)
β-pinene (1.5%)
myrcene (2.9%)
limonene (0.2%)
*cis*-sabinene hydrate (3.8%)
linalool (0.7%)
citronellal (29.7%)
borneol (2.5%)
isoborneol (1.1%)
lavandulol (0.7%)
α-terpineol (0.5%)
γ-terpineol* (9.2%)
nerol (1.5%)
geraniol (24.2%)
geranial (0.3%)
eugenol (0.5%)
β-elemene (0.2%)
β-caryophyllene (2.2%)
α-humulene (0.3%)
spathulenol (0.2%)
β-selinene (0.8%)
valencene (0.5%)
α-selinene (1.0%)
3,3,5-trimethyl-1,5-heptadiene† (0.7%)
germacrene-4-ol (1.5%)
(E)-nerolidol (4.8%)
hexadecanol (0.5%)
2-ethylhexyl phthalate‡ (2.0%)

†incorrect identification based on GC elution order; ‡plasticizer not an oil constituent; *natural occurrence of this compound is uncorroborated

Rajeswara Rao et al. (2004) compared the composition of the oil of a healthy citronella (*C. winterianus*) plant with the oil obtained from healthy leaves and the oils obtained from leaves in various stages of disease. The results of this study can be seen in T-6.

Also, Sarma et al. (2004) determined that when citronella (*C. winterianus*) was infected with leaf blight (*Curvularia* sp.), the oil content—along with almost all of the major components—are drastically reduced, as shown in T-7.

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**Comparative composition of oils isolated from healthy and diseased citronella leaves** **T-6**

| Compound | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| myrcene | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 |
| p-cymene | – | 0.1 | 0.2 | 0.1 | 0.2 |
| limonene | 1.4 | 0.1 | – | 0.2 | – |
| (Z)-β-ocimene | – | – | – | 0.1 | 0.1 |
| (E)-β-ocimene | 0.2 | 0.1 | 0.1 | 0.1 | – |
| linalool | 0.7 | 0.6 | 0.4 | 0.4 | 0.4 |
| citronellal | 28.4 | 19.1 | 17.2 | 19.1 | 13.4 |
| isopulegol | 0.4 | 0.3 | 0.3 | 0.2 | 0.3 |
| citronellol | 11.8 | 13.8 | 14.4 | 12.9 | 15.1 |
| geraniol | 24.8 | 25.5 | 24.8 | 19.0 | 22.4 |
| citronellyl acetate | 3.2 | 2.7 | 2.6 | 3.0 | 2.4 |
| geranyl acetate | 4.7 | 2.5 | 2.4 | 3.2 | 1.4 |
| β-elemene | 1.4 | 2.2 | 2.1 | 2.5 | 2.6 |
| β-caryophyllene | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| *trans*-α-bergamotene | – | 0.1 | 0.1 | 0.1 | 0.1 |
| α-humulene | – | 0.1 | 0.1 | 0.2 | 0.2 |
| γ-muurolene | 0.7 | 0.9 | 1.0 | 1.1 | 0.6 |
| α-muurolene | 0.3 | 0.5 | 0.4 | 0.4 | 0.5 |
| γ-cadinene | 0.2 | 0.4 | 0.2 | 0.2 | 0.3 |
| δ-cadinene | 0.8 | 1.3 | 1.2 | 1.2 | 1.2 |
| elemol | 10.2 | 15.3 | 16.5 | 17.9 | 20.4 |
| caryophyllene oxide | 2.2 | 3.5 | 4.0 | 3.5 | 6.0 |
| viridiflorol | 0.5 | 0.8 | 0.9 | 1.0 | 1.1 |
| 10-epi-γ-eudesmol | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 |
| T-cadinol | 1.4 | 2.0 | 2.0 | 1.5 | 1.6 |
| α-cadinol | 1.4 | 2.0 | 2.1 | 2.0 | 2.1 |
| farnesol* | 1.0 | 1.1 | 1.1 | 1.3 | 1.4 |

1 = healthy plants; 2 = healthy leaves; 3 = semidiseased leaves; 4 = crinkled diseased leaves; 5 = dead leaves; *correct isomer not identified


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**Effect of leaf blight on oil yield and main components (%) of citronella oil** **T-7**

| Compound | Healthy leaf oil | Diseased leaf oil |
|---|---|---|
| limonene | 2.5 | 1.7 |
| linalool | 0.8 | 0.4 |
| citronellal | 34.4 | 28.0 |
| citronellol | 16.6 | 7.6 |
| geraniol | 22.9 | 25.1 |
| citronellyl acetate | 5.4 | 2.6 |
| geranyl acetate | 8.8 | 4.6 |
| Oil yield | 1.47 | 1.03 |


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