Journal of Applied Botany and Food Quality 87, 56 - 61 (2014), DOI:10.5073/JABFQ.2014.087.008

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# Antifungal activity of essential oils of three aromatic plants from western Algeria against five fungal pathogens of tomato (*Lycopersicon esculentum* Mill)

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(Received December 9, 2013)

## Summary

The antifungal effect of the essential oils from *Thymus capitatus* L., *Daucus crinitus* Desf. and *Tetraclinis articulate* Vahl., aerial parts was evaluated in vitro against five phytopathogenic fungi of tomato (*Fusarium oxysporum*, *Alternaria solani*, *Aspergillus niger*, *Penicillium sp1* and *Penicillium sp2*). Our results showed that among the three plant species tested, *T. capitatus* oil was the most potent antifungal against the fungi (inhibition of mycelial growth of 100 % at a concentration of 2 µg $mL^{-1}$). Furthermore, the essential oil of *T. articulata* was also effective against *F. oxysporum*, *A. solani*, *A. niger*, *Penicillium sp1* and *Penicillium sp2* with an inhibition of mycelial growth greater than 57 % at a concentration of 5 µg $mL^{-1}$. *D. crinitus* essential oil was less effective. *T. capitatus* essential oil was dominated by carvacrol (69.6 %) and p-cymene (12.4 %). The isochavicol isobutyrate (44.9 %) and isochavicol 2-methylbutyrate (9.7 %) were the major compounds in *D. crinitus* essential oil, while the most abundant compounds in *T. articulata* were α-pinene (32.0 %), cedrol (11.0 %) and 3-carene (9.6 %). The plant essential oils were found to be an effective antifungal against of mycelial growth and, therefore, can be exploited as an ideal treatment against disease rot of tomato or as a new potential source of natural additives for the food and/or pharmaceutical industries.

## Introduction

Tomato (*Lycopersicon esculentum*) is an important commercial crop in the world. Nutritional values of tomato make it a widely accepted vegetable by consumers. Nevertheless, tomato is a very perishable vegetable with a short shelf-life and high susceptibility to fungal disease. Tomatoes are among the most popular fruits grown in Algeria. They are of an excellent quality and are greatly appreciated for their nutritional value. Furthermore, tomato production represents an important agricultural and economic activity in the country. The growing awareness of consumers concerning the relation between food and health is revolutionizing the food industry. Fungal pathogens are mainly responsible for the decay of fruits and vegetables during the postharvest period (PATHAK, 1997). *Aspergillus, Fusarium* and *Penicillium* are responsible for spoilage of many foods and causes decay on stored fruits damaged by insects, animals, early splits, and mechanical harvesting. Apart from causing diseases in plants, many species of *Aspergillus*, *Penicillium* and *Alternaria* can also synthesize mycotoxins (AGRIOS, 1997; ROJAS et al., 2005). Considerable interest has developed on the preservation of foods by the use of essential oils to effectively retard growth and mycotoxin production. Essential oils and their main components possess a wide spectrum of biological activity, which may be of great importance in several fields, from food chemistry to pharmacology and pharmaceutics (CRISTANI, 2007). The main aim of this work was to evaluate the antifungal properties of the essential oils of *T. capitatus*, *D. crinitus* and *T. articulate* against phytopathogens that cause severe diseases in tomato, such as *F. oxysporum*, *A. solani*, *A. niger*, *Penicillium sp1* and *Penicillium sp2*.

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## Materials and methods

### Plant materials and essential oils extraction

Aerial parts of *D. crinitus* were collected in Bensekrane forest area (Tlemcen Province) at the flowering stage, in June 2011. The oil yield was 0.37 % (w/w). *T. capitatus* aerial parts were collected from Beni snous in Tlemcen city at the flowering stage, during June 2011 and yielded 0.52 % (w/w). *T. articulata* aerial parts were collected from Oujlida region, Tlemcen Province during June 2011 and yielded 0.31 % (w/w). The plant species were stored at -18 °C after harvest. A portion (550-600 g) of material from each plant species was subjected to a Clevenger-type apparatus according to the European Pharmacopoeia (EUROPEAN PHARMACOPOEIA, 2004). The essential oils were dried over anhydrous sodium sulfate and, after filtration, stored in sterilized amber vials at 4 °C until it was used.

### Gas chromatography

Analyses were carried out using a Perkin Elmer Clarus 600 GC apparatus equipped with a dual flame ionization detection system and 2 fused-silica capillary columns (60 m x 0.22 mm I.D., film thickness 0.25 µm), Rtx-1 (polydimethylsiloxane) and Rtx-Wax (polyethylene glycol). The oven temperature was programmed from 60 °C to 230 °C at 2 °C/min and then held isothermally at 230 °C for 35 min. Injector and detector temperatures were maintained at 280 °C. Essential oils were injected in the split mode (1/50), using helium as the carrier gas (1 mL/min); the injection volume was 0.2 µL. Retention indices (RI) of the compounds were determined from Perkin-Elmer software.

### Gas chromatography-mass spectrometry

Essential oils were analyzed with a Perkin–Elmer TurboMass quadrupole analyzer, coupled to a Perkin–Elmer Autosystem XL, equipped with 2 fused-silica capillary columns and operated with the same GC conditions described above, except for a split of 1/80. Electronic Impact (EI) mass spectra were acquired under the following conditions: Ion source temperature 150 °C, energy ionization 70 eV, mass range 35-350 Da (scan time: 1 s).

### Component identification

The identification of the components was based on a comparison: (i) between the calculated retention indices on the polar (RI p) and apolar (RI a) columns with those of pure standard authentic compounds and literature data (JENNINGS and SHIBAMOTO, 1980; KÖNIG et al., 2001; NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY,

2008); and (ii) of the mass spectra with those of our own library of authentic compounds and with those of a commercial library (Mc Lafferty and Stauffer, 1994; Mc Lafferty and Stauffer, 1988; National Institute of Standards and Technology, 1999).

**Component quantification**

Quantification of the essential oil components was carried out using the methodology reported by Costa et al. (2008), and modified as follows. The response factor (RF) of 29 standard compounds grouped into 7 chemical groups (monoterpene hydrocarbons, sesquiterpene hydrocarbons, alcohols, ketones, aldehydes, esters, and others) was measured using GC (Znini et al., 2011). RFs and cali-bration curves were determined by diluting each standard in hexane at 5 concentrations, containing tridecane (final concentration = 0.7 g/100 g) as an internal standard. Analysis of each standard was performed in triplicate. For the quantification of the essential oil components, tridecane (0.2 g/100 g) was added as internal standard to the essential oil. The correction factor (average of the response factors from standards) of each chemical group was calculated and used to determine the essential oil component concentration (g/100 g) according to the chemical group.

**Pathogenic fungi**

*Fusarium oxysporum*, *Alternaria solani*, *Aspergillus niger*, *Penicillium sp1* and *Penicillium sp2* were isolated from naturally decayed tomato after storage of several weeks. These isolates were the most aggressive one in our collection and produced the largest lesions on inoculated fruit. A pure culture of these fungus were maintained on potato dextrose agar medium (PDA: potato 200, dextrose 20 g and agar 15 $gL^{-1}$ in distilled water at 25 °C) in the presence of a quantity of lactic acid (25 %) for stop the growth of bacteria. The plates were incubated at 25 ± 2 °C for 8 days and darkness. The developing fungal colonies were purified and identified up to the species level by microscopic examination through the help of the following references (Barnett and Hunter, 2006).

***In vitro* antifungal assay**

The antifungal activity of the three essential oils was tested using radial growth technique (Bajpai et al., 2007). Appropriate volumes of the stock solutions of the oils in dimethyl sulfoxide (DMSO) were added to PDA medium immediately before it was poured into the Petri dishes (9.0 cm diameter) at 40-45 °C to obtain two concentrations (2.0 and 5.0 µg $mL^{-1}$). Each concentration was tested in triplicate. Parallel controls were maintained with DMSO mixed with PDA. The discs of mycelial felt (0.5 cm diameter) of the plant pathogenic fungi, taken from 8-day-old cultures on PDA plates, were transferred aseptically to the centre of Petri dishes. Carbendazim was used as reference fungicide. The treatments were incubated at 27 °C in the dark. Colony growth diameter was measured after the fungal growth in the control treatments had completely covered the Petri dishes. Percentage of mycelial growth inhibition was calculated from the

formula: ($I$%) = [(DC-DT)/DC] x 100 (Pandey et al., 1982);

where DC and DT are average diameters of fungal colony of control and treatment, respectively.

**Statistical Analysis**

The inhibitory effect of essential oils on mycelial growth was expressed as mean ± standard error of mean (S.E.M.) and analyzed for ANOVA and post hoc Dunnet's t-test. The separation of means was done by using the least significant difference test at $p < 0.05$. Analysis of each test was performed in triplicate.

## Results

**Essential oils composition**

A total of 26 components accounting to 99.5 % of the essential oil composition of *T. capitatus* were identified by comparison of their EI-mass spectra and their retention indices (RI) with those of our own authentic compound library (Tab. 1). The essential oil was highly dominated by oxygenated compounds (87.1%) with high amount of aromatic terpenic components (82.6 %). However, hydrocarbons appeared also in appreciable proportion (12.4%) which monoterpene hydrocarbons are well represented (10.7 %). Indeed, the main constituents of essential oil were carvacrol (69.6 %), p-cymene (12.4 %) followed by γ-terpinene (4.3 %), myrcene (2.1 %), α-terpinene (1.7 %), linalool (1.7 %) and terpinen-4-ol (1.1 %). These results were in accordance with those previously reported in literature (Amarti et al., 2008; Bounatirou et al., 2007; Ruberto et al., 2000; Tawaha and Hudaib, 2012). Other hand, various chemical profiles of essential oils (thymol, cavacrol or thymol/carvacrol as main components) have been reported according to geographical origins of *T. capitatus* (Karouso et al., 2005; Miceli et al., 2006). The analysis of the essential oil from the aerial parts of *D. crinitus* harvested in the forest of Bensekrane (Tlemcen) identified 30 components, which accounted for 91.3 % of the total composition. Their retention indices and relative percentages are shown in Tab. 1. The main components of the aerial parts oil were phenylpropanoids isochavicol esters, principally the isochavicol isobutyrate (44.9 %). The other major components identified were: isochavicol 2-methylbutyrate (9.7 %), pentadecane (5.1 %) and undecane (4.1 %) (Tab. 1). This result is in according with literature data (Lanfranchi et al., 2010).

A total of 54 components accounting for 95.9 % of the total oil of *T. articulata* were identified (Tab. 1). The essential oils was highly dominated by the monoterpene hydrocarbons (63.8 %) followed by oxygenated sesquiterpenes (14.7 %) and sesquiterpene hydrocarbons (10.5 %). However, the oxygenated monoterpenes appeared in small proportion (6.4 %). The most abundant compounds were α-pinene (32.0 %), cedrol (11.0 %), 3-carene (9.6 %), limonene (4.3 %), sabinene (4.3 %) and (E)-β-caryophyllene (4.0 %). Ben Jemia et al. (2013) have isolated and identified, by GC-MS, 66 constituents, the major constituents of the oil are: bornyl acetate (31.4 %), α-pinene (24.5 %) and camphor (20.3 %). while Toumi et al. (2011) have identified, by GC/MS, more 45 compounds, with camphor(23.4-31,6 %), bornyl acetate (17,1-25,8 %), borneol (6.6-14,3 %), limonene (3,70-10,1 %) and α-pinene (6,5-11,3 %) were the major components of *T. articulata* essential oil. It was observed that the percentage of α-pinene (19.8-24.9 %) and bornyl acetate (40.2-59.2 %) for the leaves oils from two different sites in Algeria were the major constituents (Chikhoune et al., 2013). In addition, the percentage of cedrol and 3-carene found in our essential oil was higher than cedrol and 3-carene in previous studies. Generally, the quality and quantity of components available in essential oils may be affected by several factors, such as plant genotype, geographical condition, season, and agronomic condition (Gumus et al., 2010).

**Antifungal activity of three essential oils against the development of fungi of tomato**

The data presented in Tab. 2 show the antifungal activity of 3 plant species, belonging to 3 botanical families (Lamiaceae, Apiaceae and Cupressaceae), against *F. oxysporum*, *A. solani*, *A. niger*, *Penicillium* sp1 and *Penicillium* sp2. The effect of plant essential oils varied according to plant species. Indeed, 2 plant species out of 3 reduced

**Tab. 1:** Chemical compositions of aerial parts essential oils of *T. capitatus*, *D. crinitus* and *T. articulate*.

| No.[a] | Components | $RI_a$ [b] | $RI_a$ [c] | $RI_p$ [d] | *T. capitatus* | *D. crinitus* | *T. articulata* | Identification [e] |
|---|---|---|---|---|---|---|---|---|
| | Nonane | 906 | 902 | 907 | - | 0.6 | - | RI, MS |
| | α-Thujene | 932 | 924 | 1028 | 0.2 | - | tr | RI, MS |
| | ***α*-Pinene** | 936 | 931 | 1028 | 0.9 | 0.5 | **32.0** | RI, MS |
| | α-Fenchene | 941 | 943 | 1039 | - | - | 0.6 | RI, MS |
| | Camphene | 950 | 945 | 1071 | 0.2 | - | 0.3 | RI, MS |
| | Oct-1-en-3-ol | 962 | 962 | 1441 | 0.5 | - | - | RI, MS |
| | Sabinene | 973 | 967 | 1122 | - | 0.6 | 4.3 | RI, MS |
| | *β*-Pinene | 978 | 972 | 1113 | 0.1 | 0.1 | 1.4 | RI, MS |
| | Myrcene | 987 | 982 | 1160 | 2.1 | 0.6 | 3.3 | RI, MS |
| | *α*-Phellandrene | 1002 | 999 | 1161 | 0.2 | - | 1.5 | RI, MS |
| | 3-Carene | 1005 | 1006 | 1149 | 0.1 | - | 9.6 | RI, MS |
| | α-Terpinene | 1008 | 1011 | 1270 | 1.7 | - | - | RI, MS |
| | ***p*-Cymene** | 1015 | 1015 | 1270 | **12.4** | 0.2 | 0.5 | RI, MS |
| | Limonene | 1025 | 1023 | 1201 | - | 0.9 | 4.3 | RI, MS |
| | β-Phellandrene | 1023 | 1023 | 1209 | - | - | 1.4 | RI, MS |
| | (E)-β-Ocimene | 1041 | 1037 | 1247 | - | 0.6 | 0.7 | RI, MS |
| | (*Z*)-*β*-Ocimene | 1029 | 1022 | 1234 | 0.6 | - | - | RI, MS |
| | *γ*-Terpinene | 1051 | 1050 | 1245 | 4.3 | 1.6 | 0.7 | RI, MS |
| | (*E*)-Sabinene hydrate | 1051 | 1054 | 1445 | 0.1 | - | 0.2 | RI, MS |
| | Nonanal | 1076 | 1074 | 1403 | - | 0.1 | - | RI, MS |
| | Terpinolene | 1082 | 1079 | 1281 | 0.2 | 0.4 | 3.2 | RI, MS |
| | (Z)-Sabinene hydrate | 1087 | 1084 | 1537 | - | - | 0.8 | RI, MS |
| | Linalool | 1083 | 1085 | 1538 | 1.7 | 0.2 | 0.2 | RI, MS |
| | Undecane | 1100 | 1098 | 1101 | - | 4.1 | - | RI, MS |
| | 3-Octyl acetate | 1113 | 1107 | 1330 | - | - | 0.2 | RI, MS |
| | Veratol | 1112 | 1113 | 1713 | - | - | 0.1 | RI, MS |
| | Camphor | 1123 | 1124 | 1506 | 0.1 | - | - | RI, MS |
| | (Z)-Verbenol | 1027 | 1128 | 1642 | - | - | 0.3 | RI, MS |
| | Isoborneol | 1143 | 1144 | 1670 | 0.5 | - | - | RI, MS |
| | Borneol | 1148 | 1150 | 1688 | 0.3 | - | - | RI, MS |
| | Terpinen-4-ol | 1164 | 1162 | 1591 | 1.1 | 0.1 | 2.0 | RI, MS |
| | *α*-Terpineol | 1176 | 1176 | 1690 | 0.1 | - | 0.1 | RI, MS |
| | Octyl acetate | 1188 | 1187 | 1460 | - | 2.3 | - | RI, MS |
| | Decanal | 1188 | 1187 | 1483 | - | 1.4 | - | RI, MS |
| | Linalyl acetate | 1239 | 1239 | 1552 | - | - | 0.2 | RI, MS |
| | Decanol | 1263 | 1259 | 1729 | - | 0.1 | - | RI, MS |
| | Nonanoic acid | 1263 | 1263 | 2119 | - | 0.1 | - | RI, MS |
| | (E)-Anethole | 1264 | 1261 | 1815 | - | - | 0.1 | RI, MS |
| | Thymol | 1266 | 1263 | 2181 | 0.6 | - | - | RI, MS |
| | Bornyl acetate | 1269 | 1269 | 1562 | - | - | 0.7 | RI, MS |
| | **Carvacrol** | 1278 | 1286 | 2193 | **69.6** | - | - | RI, MS |
| | Eugenol | 1330 | 1329 | 2164 | 0,1 | - | - | RI, MS |
| | α-Terpinyl acetate | 1335 | 1333 | 1686 | - | - | 1.8 | RI, MS |
| | (E)-Myrtanyl acetate | 1366 | 1370 | 1479 | - | - | 0.1 | RI, MS |
| | β-Bourbonene | 1386 | 1384 | 1518 | - | - | 0.1 | RI, MS |
| | β-Elemene | 1389 | 1386 | 1584 | - | - | 0.2 | RI, MS |
| | Dodecanal | 1389 | 1389 | 1695 | - | 3.1 | - | RI, MS |

| No.[a] | Components | $RI_a$ [b] | $RI_a$ [c] | $RI_p$ [d] | *T. capitatus* | *D. crinitus* | *T. articulata* | Identification [e] |
|---|---|---|---|---|---|---|---|---|
| | β-Funebrene | 1419 | 1411 | 1591 | - | - | 1.6 | RI, MS |
| | (*E*)-*β*-Caryophyllene | 1421 | 1416 | 1591 | 1.6 | 0.6 | 4.0 | RI, MS |
| | Thujopsene | 1435 | 1427 | 1614 | - | - | 0.2 | RI, MS |
| | α-Humulene | 1455 | 1448 | 1668 | 0.1 | - | 2.5 | RI, MS |
| | α-Acoradiene | 1444 | 1455 | 1616 | - | - | 0.1 | RI, MS |
| | β-Acoradiene | 1458 | 1459 | 1642 | - | - | 0.1 | RI, MS |
| | Alloaromadendrene | 1462 | 1461 | 1630 | - | - | 0,1 | RI, MS |
| | γ-Curcumene | 1475 | 1471 | 1680 | - | - | 0,3 | RI, MS |
| | Germacrene D | 1479 | 1474 | 1700 | - | - | 1,3 | RI, MS |
| | β-Selinene | 1482 | 1480 | 1703 | - | - | 0,1 | RI, MS |
| | *γ*-Humulene | 1483 | 1480 | 1702 | - | 0.7 | - | RI, MS |
| | Pentadecane | 1500 | 1497 | 1502 | - | 5.1 | - | RI, MS |
| | *δ*-Cadinene | 1520 | 1511 | 1760 | - | 0.1 | 0.3 | RI, MS |
| | β-Elemol | 1535 | 1533 | 2063 | - | - | 0,4 | RI, MS |
| | **Isochavicol isobutyrate** | 1546 | 1541 | 2134 | - | **44.9** | - | RI, MS |
| | Dodecanoic acid | 1554 | 1560 | 2474 | - | 1.1 | - | RI, MS, ref |
| | Caryophyllene oxide | 1578 | 1567 | 1969 | 0.1 | - | 0.4 | RI, MS |
| | Dodecyl acetate | 1585 | 1580 | 1882 | - | 2.5 | - | RI, MS, ref |
| | Globulol | 1589 | 1577 | 2085 | - | - | 0.9 | RI, MS |
| | **Cedrol** | 1595 | 1591 | 2101 | - | - | **11.0** | RI, MS |
| | Humulene epoxide II | 1602 | 1599 | 2044 | - | - | 0.1 | RI, MS |
| | epi-Cedrol | 1613 | 1614 | 2141 | - | - | 0.2 | RI, MS |
| | α-Acorenol | 1623 | 1617 | 2106 | - | - | 0.3 | RI, MS |
| | γ-Eudesmol | 1619 | 1624 | 2198 | - | - | 0.1 | RI, MS |
| | τ-Cadinol | 1633 | 1632 | 2146 | - | - | 0.2 | RI, MS |
| | α-Eudesmol | 1632 | 1636 | 2211 | - | - | 0.3 | RI, MS |
| | **Isochavicol 2-methyl butyrate** | 1651 | 1648 | 2255 | - | **9.7** | - | RI, MS |
| | Bulnesol | 1665 | 1664 | 2198 | - | - | 0.2 | RI, MS |
| | Heptadecane | 1700 | 1703 | 1699 | - | 3.4 | - | RI, MS |
| | Tetradecanoic acid | 1761 | 1756 | 2649 | - | 3.1 | - | RI, MS, ref |
| | Cedryl acetate | 1764 | 1750 | 2160 | - | - | 0.6 | RI, MS |
| | Neophytadiene | 1807 | 1807 | 1918 | - | 0.4 | - | RI, MS, ref |
| | Hexadecanoic acid | 1951 | 1949 | 2916 | - | 1.1 | - | RI, MS |
| | Manool | 2070 | 2109 | 2684 | - | - | 0.3 | RI, MS |
| | (E)-Phytol | 2114 | 2102 | 2620 | - | 1.7 | - | RI, MS |
| | **Total identification %** | | | | **99.5** | **92.0** | **96.5** | |
| | % Hydrocarbon compounds | | | | **12.4** | **20.5** | **74.5** | |
| | % Monoterpene hydrocarbons | | | | **10.7** | 5.5 | **63.8** | |
| | % Sesquiterpene hydrocarbons | | | | 1.7 | 1.4 | 10.7 | |
| | % Non terpenic hydrocarnon compounds | | | | - | 13.2 | - | |
| | % Diterpenes hydrocarbons | | | | - | 0.4 | - | |
| | % Oxygenated compounds | | | | **87.1** | **71.5** | **22.0** | |
| | % Oxygenated monoterpenes | | | | 3.8 | 0.3 | 6.5 | |
| | % Oxygenated sesquiterpenes | | | | 0.1 | - | **14.7** | |
| | % Non terpenic oxygenated compounds | | | | 0.5 | 14.9 | 0.2 | |
| | % Aromatic compounds | | | | **82.6** | - | 0.1 | |
| | % Phenylpropanoids | | | | 0.1 | **54.6** | - | |
| | % Oxygenated diterpenes | | | | - | 1.7 | 0.5 | |

[a] Order of elution is given on apolar column (Rtx-1), [b] Retention indices on the apolar Rtx-1 column (RIa), [c] Retention indices on the polar Rtx-Wax column (RIp), [d] Retention indices on the polar Rtx-Wax column (RIp), [e] RI: Retention Indices; MS: Mass Spectrometry in EI mod.

**Tab. 2**: Percentage of inhibition of mycelial growth at various volumes of essential oils.

| **Incubation** | ***F. oxysporum*** 25°c ± 2 | ***A. solani*** 25°c ± 2 | ***A. niger*** 25°c ± 2 | ***Penicillium* sp1** 25°c ± 2 | ***Penicillium* sp2** 25°c ± 2 |
|---|---|---|---|---|---|
| Essential oil (**2 µg mL$^{-1}$**) | | | | | |
| *T. capitatus* | 100 ± 0.00 | 100 ± 0.00 | 100 ± 0.00 | 100 ± 0.00 | 100 ± 0.00 |
| *T. articulata* | 36.11± 0.08 | 35.12 ± 0.01 | 11.11± 0.11 | 34.56 ± 0.02 | 45.12± 0.06 |
| *D. crinitus* | - | - | - | - | 54.32± 0.21 |
| Essential oil (**5 µg mL$^{-1}$**) | | | | | |
| *T. articulata* | 72.22± 0.06 | 70.12± 0.20 | 57.77± 0.11 | 64.44± 0.12 | 84.44± 0.08 |
| *D. crinitus* | - | - | - | 5.55± 0.21 | 77.77± 0.06 |

mycelial growth of *F. oxysporum*, *A. solani*, *A. niger*, *Penicillium sp1* and *Penicillium sp2* by more than 50 %. Among these plants *T. capitatus*, belonging to the families of Lamiaceae, completely inhibited mycelial growth of tested fungus. *T. capitatus* essential oil produced the greatest reduction in mycelium growth with these fungi at 2 µg mL$^{-1}$, with percentage reductions of 100 % (Tab. 2). The second most effective essential oil with this five fungi was *T. articulata* essential oil, with percentage of mycelial reduction in *F. oxysporum*, *A. solani*, *A. niger*, *penicillium* sp1 and *penicillium* sp2 of 36.11, 35.12, 11.11, 34.56 and 45.12 %, respectively, at the same concentration (Tab. 2). However, the data indicate that the percentage inhibition of mycelial growth increased with increasing concentration of essential oils for all strains tested, suggesting that the essential oil of *T. articulata* inhibited the growth of all strains in a dose-dependent manner. Essential oil *D. crinitus* cause no percentage of mycelial reduction, except against *penicillium* sp2. This activity was more pronounced, where the percentage of inhibition increased to 54.32 % at 2 µg mL$^{-1}$, reaching a maximum of 77.77 % at 5 µg mL$^{-1}$, suggesting that this strain was the most sensitive to the essential oil (Tab. 2).

## Discussion

In this study, the antifungal activity of essential oils of three plant species was evaluated against *F. oxysporum*, *A. solani*, *A. niger*, *Penicillium sp1* and *Penicillium sp2*. The mycelial growth of colonies in the presence of the essential oil of *T. capitatus* and *T. articulata* showed that it effectively controlled all the fungi tested. The mycelial growth of colonies in the presence of the essential oil of *T. capitatus* and *T. articulata* showed that it effectively controlled all the fungi tested. This efficiency can be explained by the presence of active molecules that inhibited the growth of the five phytopathogenic fungi. This activity may be produced by a single major compound or by the synergistic or antagonistic effect of various compounds (Deba et al., 2008). Several authors have attributed the antifungal capacity of plant essential oils to the presence of components such as phenolic and terpene compounds (Beuchat, 1994; Davidson, 1997; Nychas, 1995) indicated that mycelial growth inhibition is caused by the monoterpenes present in essential oils. These components would increase the concentration of lipidic peroxides such as hydroxyl, alkoxy and alko peroxyl radicals and so bring about cell death. However, the influence of essential oil or bioactive compounds on flavor and aroma of tomato was not investigated and further work should be conducted to purpose the use efficiency of oil components in real applications such as fumigant. In conclusion, this paper is a part of an overall study that aims to determine the antifungal activities of natural floral resources of Algeria, in order to find new bioactive natural products. The essential oils of these plants studied, exhibited an interesting antifungal activity against mycelial growth. Further work is necessary to explore the efficacy of these essential oils against disease rot of tomato and to exploit these oils as a new potential source of natural additives for the food and/or pharmaceutical industries.

**Acknowledgements**

The authors are indebted to the Ministère des Affaires Etrangères et Européennes throughout the research program "Partenariat Hubert Curien Tassili".

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