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Efficacy of Plant Essential Oils on Postharvest Control of Rots Caused by Fungi on Different Stone Fruits In Vivo

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ABSTRACT

The antifungal activity of plant essential oils was evaluated as postharvest treatment on stone fruit against brown rot and grey mold rot of stone fruit caused by *Monilinia laxa* and *Botrytis cinerea,* respectively. The essential oils from basil (*Ocimum basilicum*), fennel (*Foeniculum sativum*), lavender (*Lavandula officinalis*), marjoram (*Origanum majorana*), oregano (*Origanum vulgare*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), sage (*Salvia officinalis*), savory (*Satureja montana*), thyme (*Thymus vulgaris*), and wild mint (*Mentha arvensis*) were tested at two different concentrations on apricots (cv. Kyoto and cv. Tonda di Costigliole), nectarines (cv. Big Top and cv. Nectaross) and plums (cv. Italia and cv. TC Sun). The volatile composition of the essential oils tested was determined by gas chromatography–mass spectrometry analysis. The treatments containing essential oils from oregano, savory, and thyme at 1% (vol/vol) controlled both *B. cinerea* and *M. laxa* growing on apricots cv. Tonda di Costigliole and plums cv. Italia and cv. TC Sun; however, the same treatments were phytotoxic for the carposphere of nectarines cv. Big Top and cv. Nectaross. Treatments with 10% (vol/vol) essential oils were highly phytotoxic, notwithstanding their efficacy against the pathogens tested. The essential oils containing as major components α-pinene, *p*-cymene, carvacrol, and thymol showed similar results on stone fruit, so their antimicrobial activity and the phytotoxicity produced could be based on the concentration of their principal compounds and their synergistic activity. The efficacy of the essential oil treatments on control of fungal pathogens in postharvest depended on the fruit cultivar, the composition and concentration of the essential oil applied, and the length of storage.

Monilinia spp. and *Botrytis cinerea* are responsible for serious postharvest diseases on stone fruits *(28)*. *Monilinia* brown rots cause significant losses in most temperate regions of the world. *Monilinia laxa* and *Monilinia fructigena* were initially observed in Europe, but now *M. laxa* is distributed in most regions where stone and pome fruit are grown *(6)*. The presence of *Monilinia fructicola,* a quarantined pathogen in Europe, regularly present in Asia, North America, and Australia, has been recently detected in Italy and other European countries, where it is rapidly replacing *M. laxa* as the main agent of brown rot on stone fruit *(25)*. In general, infections by *B. cinerea* or *Monilinia* spp. can occur as latent infections during flowering and veraison in the orchard, but rots become evident during fruit storage. *B. cinerea,* clearly one of the most significant pathogens on fruit, has been reported as the principal causative agent of blossom blight and postharvest grey mold on stone fruit *(8, 9)*. *B. cinerea* usually affects only 1 to 2% of fruit, but under conducive conditions and especially on particularly susceptible cultivars, the magnitude of losses may be much higher *(7)*.

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The emergence of resistant strains, which has limited the use of several synthetic fungicides *(3, 18, 26, 30, 31, 37)*, the lack of continued approval for some of the most effective fungicides *(11)*, and public concern over the health and environmental hazards associated with high levels of pesticide use in fruit orchards *(27, 36)* have increased the interest for developing nonchemical methods of pathogen control.

The antifungal activity of different essential oils has been reported *(4, 15, 24)*. The efficacy of some essential oils in controlling common postharvest fungi was evaluated in vitro *(5, 12, 13, 34)*, and the antifungal activity of their compounds is also well documented *(1, 33, 35)*. Previous studies showed the efficacy of oregano, savory, and thyme essential oil emulsions in controlling *B. cinerea* and *Penicillium expansum* in vivo *(17)*. The use of volatile compounds has also acquired increasing interest in recent years. Svircev et al. *(30)* demonstrated that thymol (one of the most significant active components of thyme essential oil) used in postharvest treatments has a significant effect on the cell viability and fungal hyphal structure of *M. fructicola*. The aldehydes (hexanal, *trans*-2-hexenal, citral, *trans*-cinnamaldehyde, and *p*-anisaldehyde), the phenols (carvacrol and eugenol), and the ketones (2-nonanone and

carvone) were tested for their ability to control the conidial germination and mycelial growth of *M. laxa (22),* and it was found that the best inhibition of conidial germination and mycelial growth was provided by *trans*-2-hexenal and carvacrol, respectively.

The aim of this study was to assess the efficacy of different plant essential oils, at different concentrations, in postharvest control of *B. cinerea* and *M. laxa* on different cultivars of apricots, nectarines, and plums.

MATERIALS AND METHODS

Pathogen preparation. Two strains of *B. cinerea* and two of *M. laxa* were isolated from rotten peaches and plums and tested for their virulence by inoculation in artificially wounded apricots, nectarines, and plums. They were used as a mixture throughout the work to ensure a high level of disease. Each strain was stored in slants on potato dextrose agar (Merck, Darmstadt, Germany) with 50 mg of streptomycin per liter (Merck) at 4°C. Spore suspensions were prepared by growing the pathogens on potato dextrose agar petri dishes with 50 mg of streptomycin per liter added. After 2 weeks of incubation at 20°C, spores from two strains of each pathogen species were collected and resuspended in sterile Ringer's solution (Merck). After filtering through eight layers of sterile cheesecloth, the spores were counted and brought to a concentration of 1×10^5 spores ml^{-1} for each pathogen. The resultant suspensions were shaken in a vortex mixer for 30 s before inoculation. The spore suspension was stored in sterile Falcon-type tubes at 4°C for 12 h before inoculation.

Essential oil analysis and emulsion preparation. The essential oils from basil (*Ocimum basilicum*), fennel (*Foeniculum sativum*), lavender (*Lavandula officinalis*), marjoram (*Origanum majorana*), oregano (*Origanum vulgare*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), sage (*Salvia officinalis*), savory (*Satureja montana*), thyme (*Thymus vulgaris*), and wild mint (*Mentha arvensis*), as commercial preparations with 99% purity, were purchased from Soave (Torino, Italy).

The analysis of essential oil composition was carried out by gas chromatography–mass spectrometry (GC-MS) on an Agilent Technologies 6890 series II gas chromatograph equipped with a capillary HP-5MS (30 m by 0.25 mm; film thickness of 0.25 μm) coupled to an Agilent Technologies 5973N MS instrument (Agilent Technologies, Cernusco sul Naviglio, Italy). One microliter of a hexane solution of essential oil extract was injected in split mode (1:5). The GC-MS was used under the following conditions: injector temperature, 250°C; transfer line, 280°C; the oven temperature was programmed with a initial temperature of 60°C and a final temperature of 270°C with increments of 3°C min^{-1}; and helium was used as the carrier gas under a constant flow of 1 ml min^{-1} during the entire analysis. The MS was used with the following parameters: MS source temperature, 280°C; MS quad temperature, 150°C. The autotune set was performed as follows: emission, 34.6, El Energy, 69.9; EMVolts, 2,141; AmuGain, 2,353; AmuOffs, 130; MassGain, 235; MassOffs, −9; Repeller, 17.39; IonFocus, 74; EntOffs, 13. The acquisition was set on scan mode with a scan range from 30 to 800 atomic mass units (amu); solvent delay was 3.5 min. Identification of components' essential oils was performed with the Nist Mass Spectral Search Program v2.0 using the libraries NIST 98.

To perform the treatments, a 10% (vol/vol) stock emulsion (10% essential oil, 88% sterilized water, and 2% Tween 20; Merck) and a 1% (vol/vol) emulsion (10% stock emulsion and 90% sterilized water) were prepared from each essential oil. All the resultant emulsions were shaken for 30 s before application to ensure a homogeneous essential oil mixture.

Efficacy of essential oil treatments. Apricots (*Prunus armeniaca,* cv. Kyoto and cv. Tonda di Costigliole), nectarines (*Prunus persica* var. *nectarine,* cv. Big Top and cv. Nectaross), and plums (*Prunus domestica,* cv. Italia and cv. TC Sun), harvested in orchards in northern Italy following integrated pest management practices, were divided in groups of 45 fruits per treatment. All the fruits, free from evident wounds and rot, were disinfected in 1% sodium hypochloride solution, rinsed in tap water, dried at room temperature, and punctured with a sterile plastic tip at the equatorial region (3 mm deep and 3 mm wide; three wounds per fruit). A volume of pathogen suspension (10 μl; 1×10^5 spores ml^{-1}) was dropped into each wound. Fruits were kept at room temperature for 12 h to help the establishment of the pathogen. Then, 10 μl of essential oil emulsion was dropped into each inoculated wound. A tebuconazole suspension, made with 0.5 g of water-dispersible granules with 25% tebuconazole in 1 liter of water, was used as a chemical control by dropping 10 μl of suspension into each inoculated wound. An inoculated control was also prepared. All treatments, the chemical control, and the inoculated control were stored in cold chambers at 1.0 ± 1°C for 28 days. The diameter of the rot around each wound was measured after 14 and 28 days of storage. Phytotoxicity symptoms (observed at the end of the storage as circular light burns on the fruit carposphere around the artificial wounds) on treated fruit were registered when detected. Each trial was performed three times.

Statistical analysis. Data from three trials were pooled together, the statistical analysis was performed by one-way analysis of variance using SPSS-WIN software, and Duncan's multiple range test was utilized; P values of <0.05 were considered significant.

RESULTS

Essential oil analysis. The composition of the essential oils tested was determined through GC-MS analysis. Compounds representing at least 3% of the composition of the essential oils were considered as relevant; the component percentages are reported in Table 1. Myrcene and α-pinene were present in all essential oils analyzed, but only in rosemary, sage, savory, and thyme essential oils was α-pinene a relevant compound (25.17, 7.38, 9.35, and 19.78%, respectively). On the contrary, myrcene never surpassed 1% (it reached 0.99% in marjoram essential oil). Eucalyptol was present in almost all essential oils, but it was a major compound in marjoram, rosemary, and sage essential oils. Anethole was present only in fennel essential oil, and its concentration was 59.26% of the sample. Relevant concentrations of α-pinene, *p*-cymene, carvacrol, and thymol were detected only in oregano, savory, and thyme essential oils.

Efficacy against grey mold. The treatments with basil, lavender, mint, and peppermint essential oil emulsions at 10% against *B. cinerea* on both cultivars of apricots showed an efficacy statistically similar to that of the chemical control already after 14 days of storage (Fig. 1); treatments with oregano and savory essential oil emulsions at 10% were more effective on apricots cv. Tonda di Costigliole than on cv. Kyoto. On nectarines cv. Big Top, the treatment with oregano essential oil emulsion at 10% presented an

TABLE 1. *Chemical composition of the essential oils tested in this study*[a]

Compound	RI[b]	Basil	Fennel	Lavender	Marjoram	Mint	Peppermint	Oregano	Rosemary	Sage	Savory	Thyme
α-Pinene	939								25.17	7.38	9.35	19.78
Camphene	954								6.91	10.01		
β-Pinene	979				4.63				4.98	3.08		
p-Cymene	1025							10.90			16.05	3.62
o-Cymene	1026								4.76	3.04		
Limonene	1029				3.65	5.75						
Eucalyptol	1031	5.24		5.87	50.24			3.73	27.59	26.12	3.20	
γ-Terpinene	1060							10.58				
Fenchone	1087		12.72									
Linalool	1097	36.32		28.41	27.10			6.36			3.51	8.33
Camphor	1146			8.28					15.51	30.12		
Menthone	1153					20.75	24.19					
Isomenthone	1163					10.68						
Menthofuranol	1164						6.88					
Menthol	1172					33.33	42.13					
Estragole	1196	10.84	3.79									
Linalyl acetate	1234			35.38	3.45							
p-Anilsaldehyde	1250		4.37									
Anethole	1253		59.26									
Lavandulyl acetate	1290			3.19								
Thymol	1291							21.06			14.20	53.70
Menthyl acetate	1295					6.96	5.75					
Carvacrol	1299							30.64			45.14	3.10
Eugenol	1359	20.64										
Z-caryophyllene	1409							3.85	3.76			
Anysil acetate	1413		4.18									
Bergamotene	1413	3.47										
α-Cadinol	1654	3.43										
Other compounds (<3%)		16.02	6.43	11.21	10.20	11.21	13.04	7.00	7.73	17.87	7.33	6.60
All identified compounds		95.96	90.75	92.34	99.27	88.68	91.99	94.12	96.41	97.62	98.78	95.13

[a] Values are percentages. Compounds representing over 3% of the essential oils are reported.
[b] RI, retention index in the HP-INNOVAX capillary column.

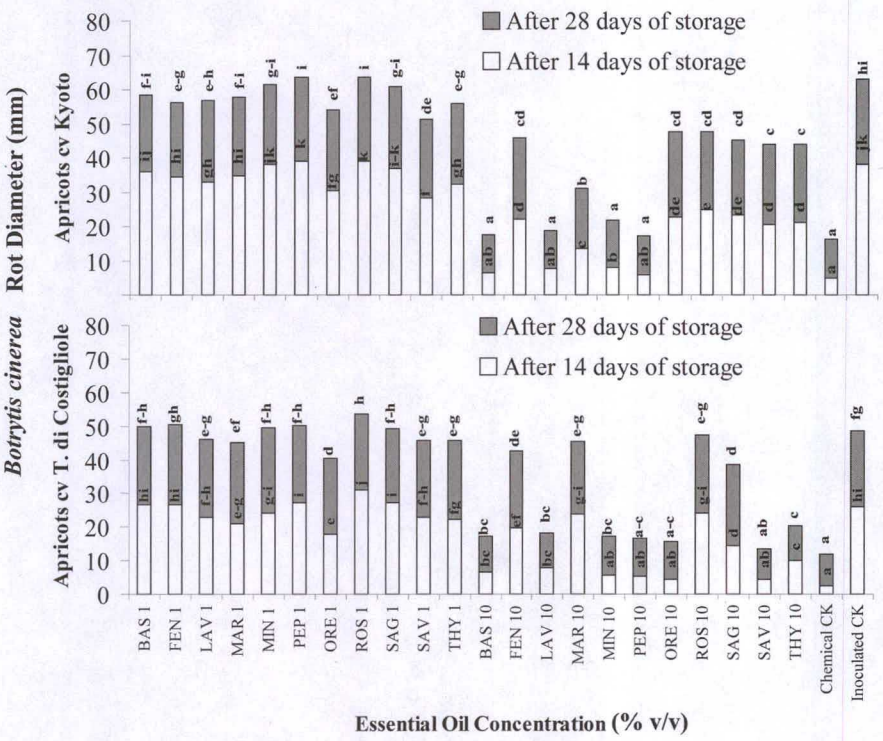

FIGURE 1. *Efficacy of essential oil treatments expressed as rot diameter (in millimeters) caused by* B. cinerea *on apricots (45 fruits per treatment) cv. Kyoto and cv. Tonda di Costigliole stored at 1.0 ± 1°C for 28 days after artificial inoculation. Treatments were performed with essential oils of* O. basilicum *(BAS),* F. sativum *(FEN),* L. officinalis *(LAV),* O. majorana *(MAR),* O. vulgare *(ORE),* M. piperita *(PEP),* R. officinalis *(ROS),* S. officinalis *(SAG),* S. montana *(SAV),* T. vulgaris *(THY), and* M. arvensis *(MIN) at 1 or 10% (vol/vol) concentrations. Values followed by the same letter are not statistically different by Duncan's multiple range test* ($P < 0.05$).

efficacy statistically similar to that of the chemical control, but on nectarines cv. Nectaross, only the treatment with thyme essential oil emulsion at 10% produced such results (Fig. 2). On both plum cultivars, treatments with oregano essential oil at 10% showed an efficacy statistically similar to that of the chemical control after 14 and 28 days of storage (Fig. 3); on plums cv. Italia also, the efficacy of the treatments with savory and thyme essential oils at 10% was statistically similar to that of the chemical control after 28 days of storage.

Efficacy against brown rot. After 28 days of storage, on both cultivars of apricots, the treatments with basil, wild mint, and peppermint essential oil emulsions at 10% presented an efficacy statistically similar to that of the chemical control against *M. laxa* (Fig. 4). On apricots cv. Tonda di Costigliole, the treatments with oregano, savory, and thyme essential oils at 10% produced results also statistically similar to that of the chemical control after 28 days of storage, while the same treatments produced phytotoxicity on apricots cv. Kyoto. The treatments with

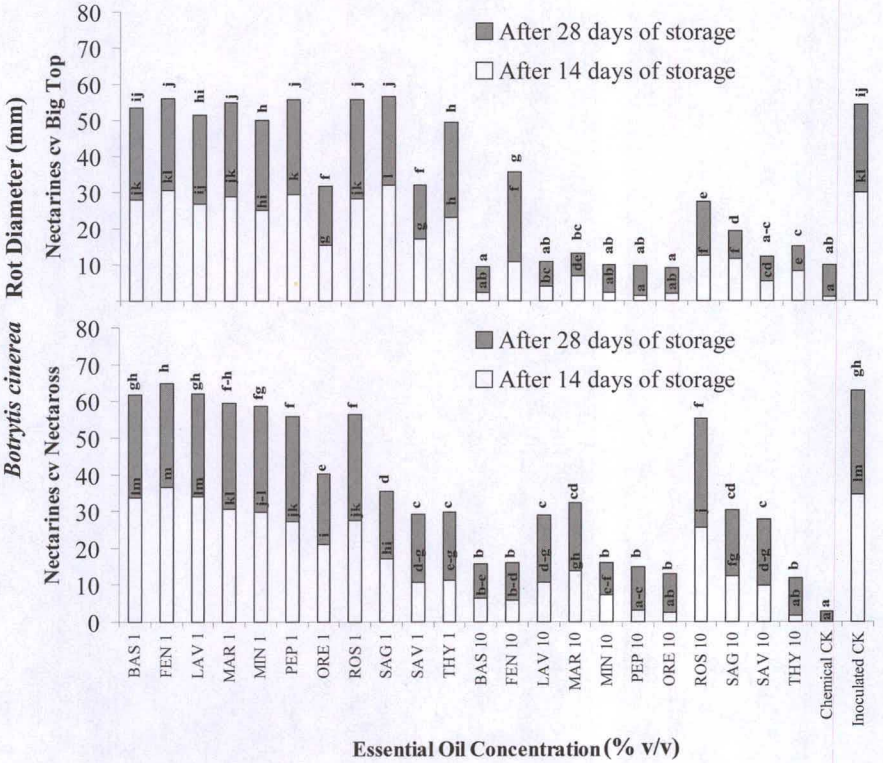

FIGURE 2. *Efficacy of essential oil treatments expressed as rot diameter (in millimeters) caused by* B. cinerea *on nectarines (45 fruits per treatment) cv. Big Top and cv. Nectaross stored at 1.0 ± 1°C for 28 days after artificial inoculation. Treatments were performed with essential oils of* O. basilicum *(BAS),* F. sativum *(FEN),* L. officinalis *(LAV),* O. majorana *(MAR),* O. vulgare *(ORE),* M. piperita *(PEP),* R. officinalis *(ROS),* S. officinalis *(SAG),* S. montana *(SAV),* T. vulgaris *(THY), and* M. arvensis *(MIN) at 1 or 10% (vol/vol) concentrations. Values followed by the same letter are not statistically different by Duncan's multiple range test* ($P < 0.05$).

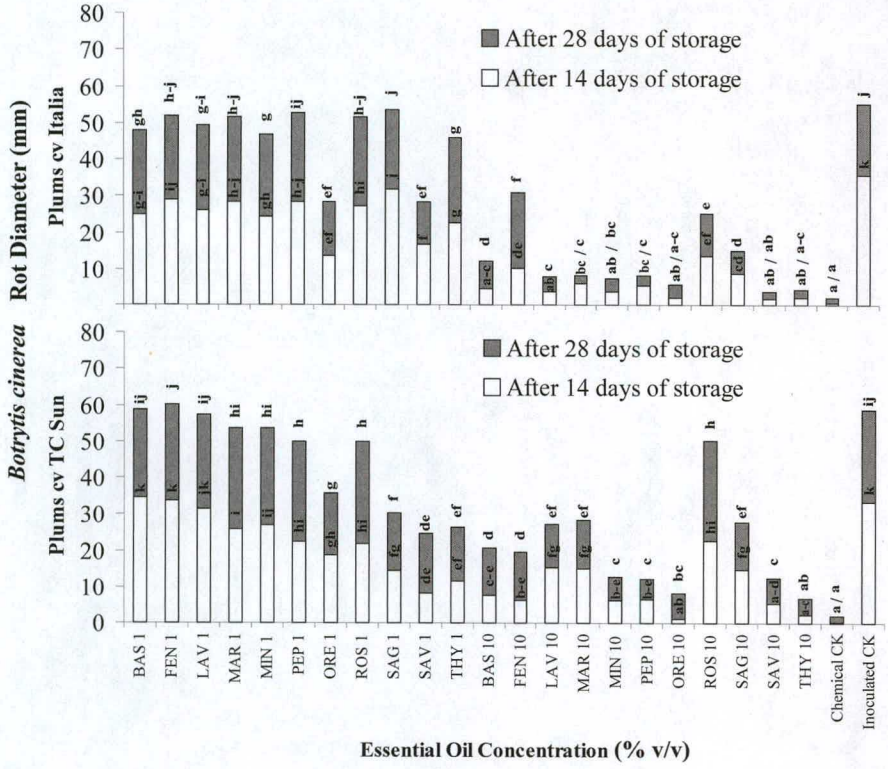

FIGURE 3. *Efficacy of essential oil treatments expressed as rot diameter (in millimeters) caused by* B. cinerea *on plums (45 fruit per treatment) cv. Italia and cv. TC Sun stored at 1.0 ± 1°C for 28 days after artificial inoculation. Treatments were performed with essential oils of* O. basilicum *(BAS),* F. sativum *(FEN),* L. officinalis *(LAV),* O. majorana *(MAR),* O. vulgare *(ORE),* M. piperita *(PEP),* R. officinalis *(ROS),* S. officinalis *(SAG),* S. montana *(SAV),* T. vulgaris *(THY), and* M. arvensis *(MIN) at 1 or 10% (vol/vol) concentrations. Values followed by the same letter are not statistically different by Duncan's multiple range test* ($P < 0.05$).

savory and thyme essential oils at 10% were highly phytotoxic for both cultivars on which *M. laxa* was tested, as well as the treatments with oregano essential oil at 10% on all trials on nectarines (Fig. 5). The treatments with essential oils from savory and thyme at 10% showed an efficacy statistically similar to that of the chemical control after 28 days of storage on both cultivars of plums (Fig. 6), and the treatments with basil, lavender, marjoram, wild mint, peppermint, and oregano essential oils at 10% also presented an efficacy similar to that of the chemical control but only on plums cv. Italia and only after 14 days of storage.

Phytotoxicity of the treatments. After treatments with essential oil at 10%, apricots cv. Kyoto and both nectarine cultivars were more prone to phytotoxicity than apricots cv. Tonda di Costigliole and both plum cultivars. The presence

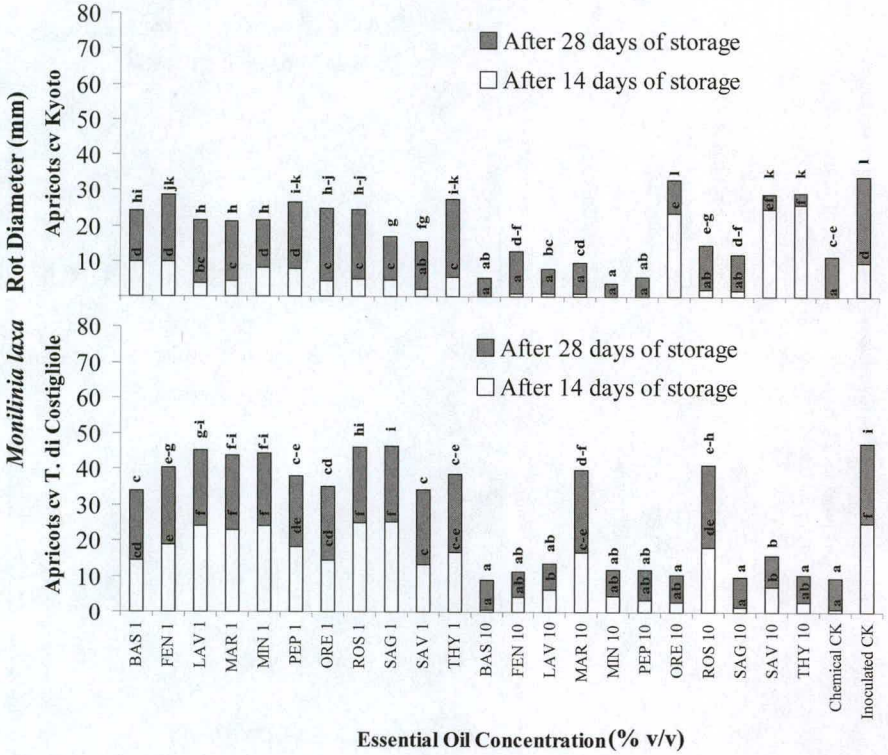

FIGURE 4. *Efficacy of essential oil treatments expressed as rot diameter (in millimeters) caused by* M. laxa *on apricots (45 fruits per treatment) cv. Kyoto and cv. Tonda di Costigliole stored at 1.0 ± 1°C for 28 days after artificial inoculation. Treatments were performed with essential oils of* O. basilicum *(BAS),* F. sativum *(FEN),* L. officinalis *(LAV),* O. majorana *(MAR),* O. vulgare *(ORE),* M. piperita *(PEP),* R. officinalis *(ROS),* S. officinalis *(SAG),* S. montana *(SAV),* T. vulgaris *(THY), and* M. arvensis *(MIN) at 1 or 10% (vol/vol) concentrations. Values followed by the same letter are not statistically different by Duncan's multiple range test* ($P < 0.05$).

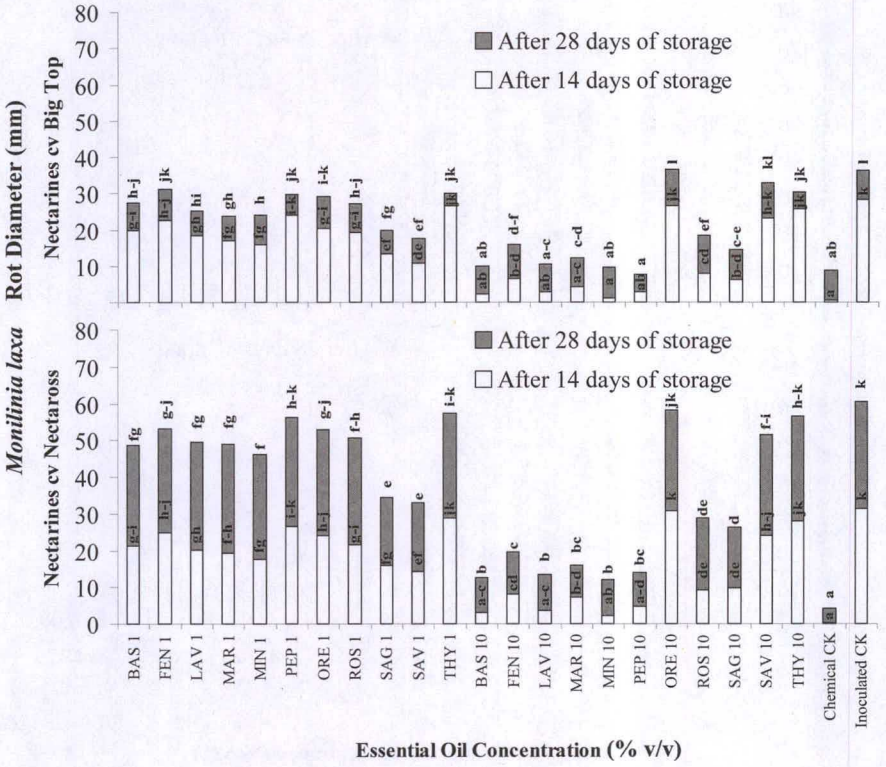

FIGURE 5. *Efficacy of essential oil treatments expressed as rot diameter (in millimeters) caused by* M. laxa *on nectarines (45 fruits per treatment) cv. Big Top and cv. Nectaross stored at 1.0 ± 1°C for 28 days after artificial inoculation. Treatments were performed with essential oils of* O. basilicum *(BAS),* F. sativum *(FEN),* L. officinalis *(LAV),* O. majorana *(MAR),* O. vulgare *(ORE),* M. piperita *(PEP),* R. officinalis *(ROS),* S. officinalis *(SAG),* S. montana *(SAV),* T. vulgaris *(THY), and* M. arvensis *(MIN) at 1 or 10% (vol/vol) concentrations. Values followed by the same letter are not statistically different by Duncan's multiple range test* ($P < 0.05$).

of phytotoxicity is reported in Table 2. An example of phytotoxicity symptoms on the carposphere of stone fruit is illustrated in Figure 7.

DISCUSSION

Results in vivo provided an improved comprehension of the antifungal activity of essential oil emulsions as postharvest treatments on fruit and the side effect of phytotoxicity. The treatments performed with essential oil emulsions at 10% were more effective than those at 1% against the tested pathogens; however, treatments with a 10% concentration of basil, peppermint, oregano, savory, and thyme essential oils were phytotoxic on fruit. Not only did apricots cv. Kyoto and both cultivars of nectarines show phytotoxicity symptoms caused by the above-mentioned

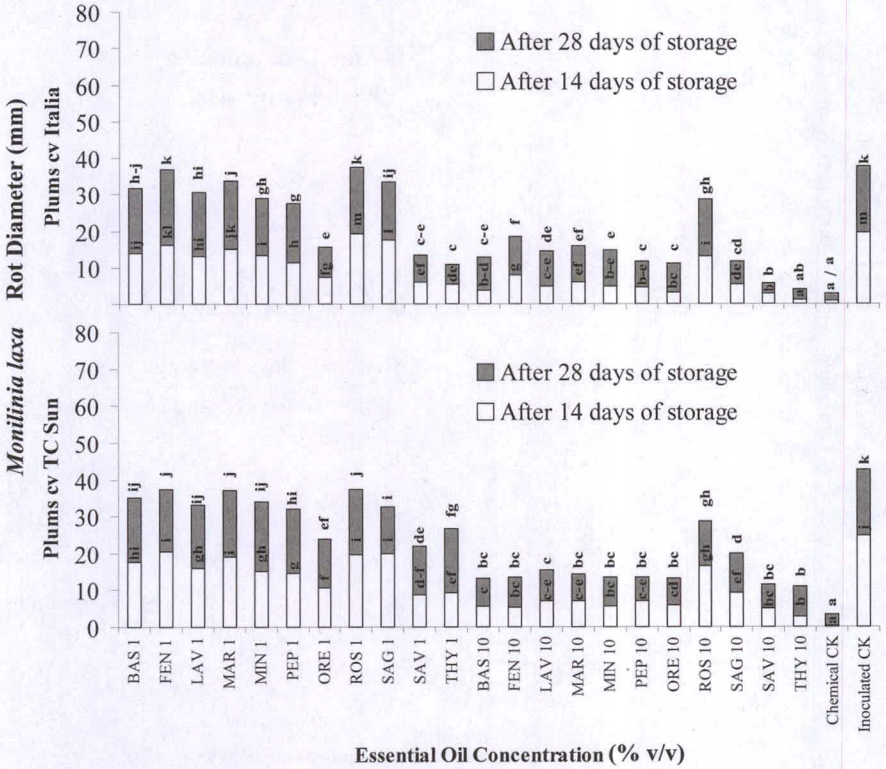

FIGURE 6. *Efficacy of essential oil treatments expressed as rot diameter (in millimeters) caused by* M. laxa *on plums (45 fruits per treatment) cv. Italia and cv. TC Sun stored at 1.0 ± 1°C for 28 days after artificial inoculation. Treatments were performed with essential oils of* O. basilicum *(BAS),* F. sativum *(FEN),* L. officinalis *(LAV),* O. majorana *(MAR),* O. vulgare *(ORE),* M. piperita *(PEP),* R. officinalis *(ROS),* S. officinalis *(SAG),* S. montana *(SAV),* T. vulgaris *(THY), and* M. arvensis *(MIN) at 1 or 10% (vol/vol) concentrations. Values followed by the same letter are not statistically different by Duncan's multiple range test* ($P < 0.05$).

TABLE 2. *Phytotoxicity detected on the carposphere of fruit treated with essential oil emulsions*[a]

	Apricots		Nectarines		Plums	
Treatment (% concn)	cv. Kyoto	cv. Tonda di Costigliole	cv. Big Top	cv. Nectaross	cv. Italia	cv. TC Sun
Basil (1)	+	−	+	+	−	−
Fennel (1)	−	−	−	−	−	−
Lavender (1)	−	−	−	−	−	−
Marjoram (1)	−	−	−	−	−	−
Wild mint (1)	−	−	−	−	−	−
Peppermint (1)	−	−	−	−	−	−
Oregano (1)	+	−	+	+	−	−
Rosemary (1)	−	−	−	−	−	−
Sage (1)	−	−	−	−	−	−
Savory (1)	+	−	+	+	−	−
Thyme (1)	+	−	+	+	−	−
Basil (10)	+	+	+	+	+	+
Fennel (10)	+	+	+	+	−	+
Lavender (10)	+	−	+	−	−	+
Marjoram (10)	+	−	+	+	−	−
Wild mint (10)	+	+	+	+	−	+
Peppermint (10)	+	+	+	+	+	+
Oregano (10)	+	+	+	+	+	+
Rosemary (10)	+	−	−	−	−	−
Sage (10)	+	+	+	+	−	−
Savory (10)	+	+	+	+	+	+
Thyme (10)	+	+	+	+	+	+

[a] +, presence of phytotoxicity symptoms; −, absence of phytotoxicity symptoms.

treatments, but also these fruit cultivars were recolonized, mostly due to the nesting ability of *B. cinerea* and *M. laxa,* showing increasing rot diameters between the 14th and the 28th days of storage. The treatments with basil, wild mint, peppermint, and oregano essential oils at 10% showed relevant results in controlling the tested pathogens, particularly against *B. cinerea* after 14 days of storage, but after 28 days of storage their activity on rot diameter was no longer effective. In spite of their collateral effects on apricots and nectarines, the treatments with the essential oils from oregano, savory, and thyme controlled the tested pathogens after both 14 and 28 days of storage. Essential oils could be used for short storage times, or the treatment could be repeated after a defined time period *(17).*

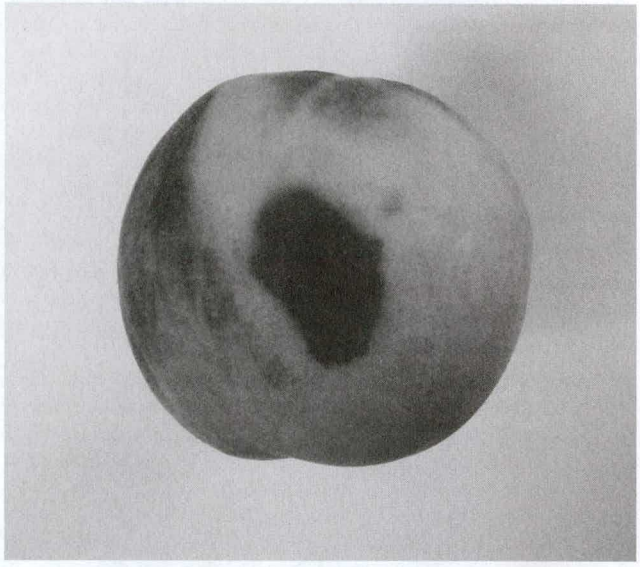

FIGURE 7. *Phytotoxicity caused by thyme essential oil treatment at 10% on a nectarine cv. Big Top.*

The treatments with oregano, savory, and thyme essential oils showed similar results on stone fruit; indeed, α-pinene, *p*-cymene, carvacrol, and thymol were detected as their major compounds at different concentrations. Then, the antimicrobial activity and the phytotoxicity showed by the essential oil treatments could also be based on the concentration of their major compounds and their synergy, as previously shown against foodborne agents such as *Staphylococcus aureus (14),* since in most cases the antimicrobial activity of different compounds is enhanced when they are combined *(21, 23).* In our experiments, we could hypothesize that the major components of thyme and savory essential oils, which are α-pinene, thymol, *p*-cymene, and carvacrol, could explain most of the antimicrobial effect. Svircev et al. *(30)* and Neri et al. *(22)* have already shown that thymol and carvacrol possess antimicrobial activity when applied alone.

By comparing the results obtained for different stone fruit species, it is possible to conclude that apricots were more susceptible than nectarines and plums to the tested pathogens; a comparison between cultivars shows that apricots cv. Kyoto, nectarines cv. Big Top, and plums cv. TC Sun were more susceptible than apricots cv. Tonda di Costigliole, nectarines cv. Nectaross, and plums cv. Italia. A similar behavior was reported by Liu et al. *(16)* after

fumigation with thymol, one of the most important components of thyme essential oil. In fact, even between different cultivars of the same species, epidermis structures, such as thick cuticles and the presence of epicuticular waxes, could determine a higher resistance to brown rot *(10)*. These structural and biochemical components of stone fruits could also be related to the observed side effects of essential oil treatments in postharvest.

The bioactivity of the vapor phase of essential oils was recognized as a characteristic that makes them attractive as possible fumigants for stored product protection; in fact, some essential oils have been reported to protect stored food commodities from biodeterioration *(32)*. Consequently, the vapor application method could enhance the efficacy of postharvest treatments with essential oils *(2)*, as could its combination with other innovative postharvest treatments, such as the application of biocontrol agents *(29)*, or its integration with available technologies in the packinghouses, such as controlled atmosphere storage *(20)*. The implementation of essential oil treatments during postharvest storage of stone fruit is very promising because of their compatibility with other traditional and innovative technologies and may be further transferred to other fruit and vegetables. The approximate cost to treat stone fruits with savory or thyme essential oils at 1% could increase the final price by approximately 0.38% (0.23 €cent) per kg of fruit; of course, essential oils obtained from plants such as peppermint are more expensive, and this would be directly reflected in the price of treated fruit. The approximate cost for treating with savory or thyme essential oils at 10% would be 2.3 €cent per kg of fruit (3.8% of the fruit value).

Essential oil treatments proved to be an effective method for controlling *B. cinerea* and *M. laxa* on stone fruit, but their efficacy in postharvest could depend on the fruit cultivar, the composition and concentration of the essential oil applied, and the length of storage. Doubtless, the results obtained under controlled conditions should be validated under semicommercial conditions with intermediate concentrations, aiming at the preservation of the organoleptic properties of fruit. Treatments with 0.1 and 100% of essential oils were used in preliminary assays (data not shown) but rejected because pure essential oil treatments were highly phytotoxic and economically unsustainable, while 0.1% treatments did not guarantee a significant efficacy on pathogen control. Furthermore, for peaches treated with 1% essential oils (data not shown) significant changes in taste and flavor were not shown, as reported also for pears treated with *Thymus kotschyanus, O. basilicum,* and *R. officinalis* essential oils *(19)*. However, it could be advised to keep the treated fruit in the open air for at least 12 h after storage.

Treatments containing essential oils from oregano, savory, and thyme at 1% would be suitable for controlling both *B. cinerea* and *M. laxa* on apricots cv. Tonda di Costigliole and on plums cv. Italia and cv. TC Sun. The side effects caused by these essential oils on apricots cv. Kyoto and nectarines cv. Big Top and cv. Nectaross could be reduced by changing the application method and the frequency of the treatments, as appropriate for lower concentrations of the essential oils. Moreover, we plan to test the single components of the most effective essential oils. Finally, additional research on optimizing the essential oil treatments is needed to guarantee an effective and safe control of postharvest diseases of fruit.

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