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Control of anthracnose, caused by *Colletotrichum musae*, on postharvest organic banana by thyme oil

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ABSTRACT

Anthracnose in organic bananas is an aggressive, difficult to control postharvest disease. Essential oils have been studied in order incorporate them into integrated pest management, and to reduce synthetic fungicides during the postharvest period. *In vitro* assays showed that thyme oil was the best essential oil to control mycelial growth of *Colletotrichum musae*. This essential oil was tested *in vivo* because of its fungicidal effect. The results showed that, after storage and shelf life at 20 °C, severity inhibition of *C. musae* on fruit treated with 500 μL L^{-1} of thyme oil (30.8%) was higher ($p < 0.05$) than with other treatments. Moreover, 500 μL L^{-1} of thyme oil reduced weight loss, retained color and firmness, and slowed the changes of chemical parameters in organic bananas during storage. After the postharvest period, panelists did not detect thyme oil odor, and overall appearance was also better, when using thyme oil, than in non-treated fruit. These results suggest that thyme oil may be potentially used for controlling anthracnose in organic bananas during the postharvest period, without a negative effect on its physicochemical and sensory quality.

1. Introduction

Consumer preference for organic fresh fruit is intensifying and becoming popular in developed countries. In Ecuador, organic bananas (*Musa acuminata*) represent 3% of the country's total production (Banco Central de Ecuador, 2015). In general, bananas are the eighth most important food crop in the world (Ploetz, 2015) and ranks as the most valuable agricultural commodity in Ecuador. In 2013, the gross production value of this fruit in Ecuador was US$ 1.32 billion (FAOSTAT, 2017). As a tropical climacteric commodity, the storage and transport of bananas have serious limitations that result in their rapid deterioration and high incidence of rot during handling and conservation (Alemu, 2014; Ahmed and Palta, 2016; Chen et al., 2017). Additionally, because of the absence of pesticide treatments and the interval of time from harvest to market, organic banana is more susceptible to postharvest diseases which impair its quality than conventional crops (Alvinia, 2012). Postharvest decay due to fungal pathogens is one of the most important factors causing economic losses in the worldwide industry (Ranasinghe et al., 2003; Mari et al., 2016; Palou et al., 2016).

Anthracnose, caused by *C. musae*, is the most aggressive disease during the postharvest of bananas (Williamson et al., 2008; Maqbool et al., 2010; Alemu, 2014), and limits good fruit quality. *C. musae* causes a latent, subcuticular infection in the field during early stages of fruit development; however, disease symptoms on the banana peel (sunken brown-black lesions) only develop after harvest, usually during fruit ripening (Krauss et al., 1998; De Costa and Erabadupitiya, 2005; Sivakumar and Bautista-Baños, 2014). Postharvest losses due to anthracnose increase up to 80% if the fruit is not treated (Bill et al., 2014). Thus, any potential control measure which can effectively delay symptoms of anthracnose infection would have an important role in extending the shelf life of bananas during storage (Maqbool et al., 2010)

Chemical fungicides, like imazalil, are commonly used to control anthracnose in bananas during the postharvest period in order to prolong the shelf life of fresh fruit. Although the control of postharvest pathogens currently still relies mainly on the application of fungicides, because of the short time between treatment and consumption, there are strong public and scientific demands against the use of chemical fungicides in order to prevent carcinogenic impacts, residual toxicity, ecological pollution and particularly the fungicide-resistance development (Cindi et al., 2015; Farzaneh et al., 2015; Abdel-Rahim and Abo-Elyousr, 2017).

In the last decade consumer requirement for high quality fruit with few pesticide residues, has induced countries to reinforce strict import and export regulations regarding the maximum limits of these residues in the edible portion of the fruit (Sivakumar and Bautista-Baños, 2014;

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Table 1
In vitro mycelial growth inhibition (MGI) of essential oils against *C. musae* HBAN-18.

MGI (%)								
Essential oil	500 μL L^{-1}		1000 μL L^{-1}		1500 μL L^{-1}		2000 μL L^{-1}	
	6 d	12 d	6 d	12 d	6 d	12 d	6 d	12 d
Thyme *(Thymus vulgaris* L.)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
Lavender *(Lavandula angustifolia* Mill.)	75 ± 10.0^{c}	63 ± 9.9^{d}	78 ± 10.8^{c}	80 ± 11.5^{c}	80 ± 10.7^{c}	83 ± 11.3^{c}	83 ± 10.8^{c}	84 ± 11.1^{c}
Rosemary *(Rosmarinus officinalis* L.)	38 ± 14.6^{f}	20 ± 4.1^{f}	39 ± 12.1^{e}	23 ± 6.9^{e}	39 ± 6.4^{e}	21 ± 5.3^{e}	57 ± 6.0^{e}	36 ± 9.0^{e}
Mint *(Mentha x piperita* L.)	72 ± 10.1^{d}	71 ± 5.6^{c}	79 ± 8.3^{c}	81 ± 8.6^{c}	80 ± 9.4^{c}	92 ± 1.6^{b}	92 ± 10.6^{b}	97 ± 10.7^{b}
Basil *(Ocimum basilicum* L.)	78 ± 5.7^{b}	85 ± 7.6^{b}	91 ± 10.9^{b}	87 ± 12.0^{b}	93 ± 9.9^{b}	89 ± 12.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
Grapefruit *(Citrus x paradisi* Macfady)	51 ± 7.5^{e}	46 ± 10.6^{e}	58 ± 14.4^{d}	53 ± 9.0^{d}	60 ± 10.3^{d}	55 ± 7.7^{d}	67 ± 8.6^{d}	61 ± 4.2^{d}

Means ± SD in the same column with different letters are significantly different according LSD test ($p < 0.05$). LSD = 1.261.

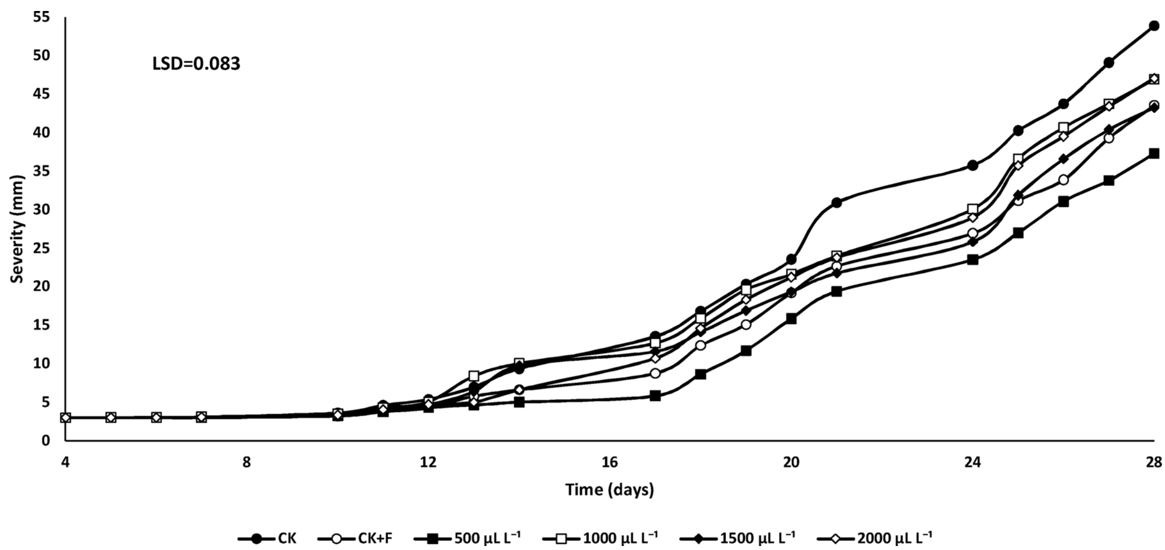

Fig. 1. Severity (mm) caused by *C. musae* HBAN-18 in organic bananas treated with thyme oil over 21 d of cold storage at 13 °C plus 7 d of shelf life at 20 °C (28 d). (●) CK (control fruit): non-treated; (○) CK + F: imazalil (0.6 g L^{-1}); and thyme oil treatments: (■) 500 μL L^{-1}; (□) 1000 μL L^{-1}; (◆) 1500 μL L^{-1} and (◊) 2000 μL L^{-1}. Each point represents the mean of twenty different fruit LSD ($p < 0.05$).

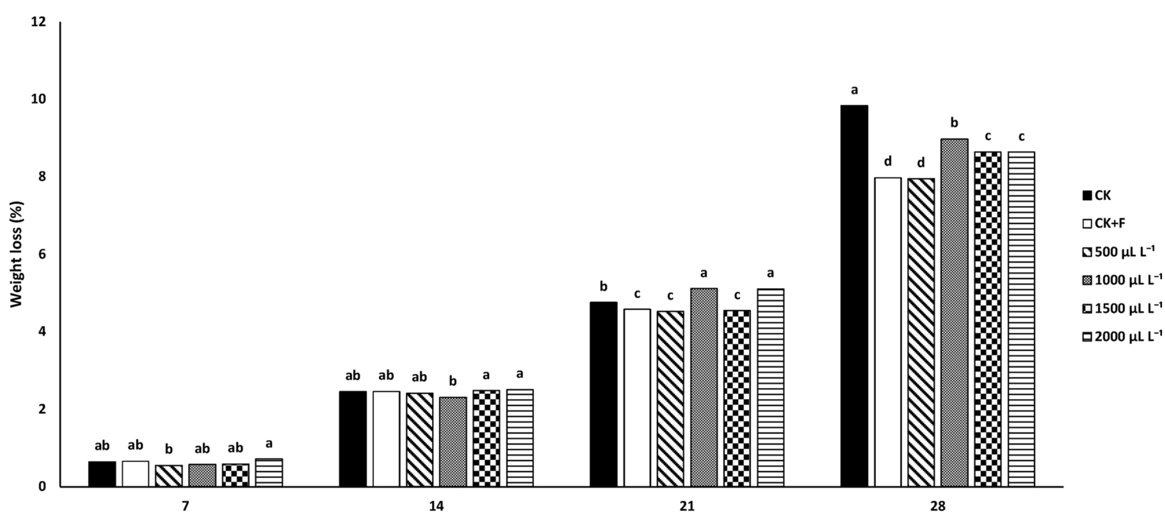

Fig. 2. Weight loss (%) in organic bananas inoculated with *C. musae* HBAN-18 and treated with thyme oil over 21 d of cold storage at 13 °C plus 7 d of shelf life at 20 °C (28 d). (■) CK (control fruit): non-treated; (□) CK + F: imazalil (0.6 g L^{-1}); and thyme oil treatments: (▧) 500 μL L^{-1}; (▩) 1000 μL L^{-1}; (▚) 1500 μL L^{-1} and (▤) 2000 μL L^{-1}. Each bar represents the mean of twenty different fruit LSD = 0.151 ($p < 0.05$).

Guerra et al., 2015). Due to these requirements for natural alternatives to synthetic compounds associated with food preservation, have led to the search for naturally derived antimicrobials. Essential oils extracted from aromatic and medicinal plants have a broad antimicrobial and antifungal spectrum (Perdones et al., 2012; Khalili et al., 2015; Campos-Requena et al., 2017), which could be an ecological and economical solution (Gilles et al., 2010) and their usage complies with consumers' expectations for safe and nutritional fruit (Munhuweyi et al., 2017).