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Repellent, attractive, and insecticidal effects of essential oils from *Schinus terebinthifolius* fruits and *Corymbia citriodora* leaves on two whitefly species, *Bemisia tabaci*, and *Trialeurodes ricini*

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ABSTRACT

In this study, the repellent, attractive, and insecticidal effects of essential oils (EOs) from *Schinus terebinthifolius* Raddi fruit and *Eucalyptus citriodora* Hook. (*Corymbia citriodora* (Hook.) K.D.Hill & L.A.S. Johnson) leaves on the sweet-potato whitefly (*Bemisia tabaci* Gennadius) and the castor bean whitefly (*Trialeurodes ricini* Misra) were evaluated. The olfaction response of *B. tabaci* and *T. ricini* was investigated under laboratory conditions by exposing adults to the odor of the EOs from *S. terebinthifolius* fruits and *C. citriodora* leaves using a specially designed glass olfactometer at five concentrations ranging from 0.01% to 1.0%. In addition, the insecticidal effect was evaluated under greenhouse conditions using five concentrations of EOs (25, 50, 100, 500 and 1000 ppm) applied in contact toxicity experiments. The results revealed that repellency or attractiveness of the tested EOs varied significantly according to the EO type, concentration, and whitefly species. The maximum insect attraction was obtained with 0.5% *C. citriodora* leaf EO on *T. ricini* (229.03%). Conversely, the greatest repellency was observed with 1% *S. terebinthifolius* fruit EO on *B. tabaci* (37.84%). EOs from *S. terebinthifolius* fruit were the most potent against *T. ricini* adults, with an LC_{50} value of 19.622 ppm. Conversely, *C. citriodora* was less toxic for *B. tabaci* adults, with an LC_{50} value of 249.453 ppm, compared with controls. The present study suggests that the tested EOs may be suitable as alternative compounds in integrated pest management programs for *B. tabaci* and *T. ricini*. Moreover, their non-toxic and environmentally acceptable nature makes them safe to apply to plant crops.

1. Introduction

Whiteflies damage plants by sucking their sap and through the development of sooty mold on secreted honeydew. They are also capable of transmitting more than 100 viral diseases that can contribute to significant losses in many economically important crops (Brown et al., 1995; Oliveira et al., 2001; Wan et al., 2009). At least twenty-one aleyrodid pests have been documented in the Egyptian cropping system, with three of these (*Bemisia tabaci*, *B. argentifolii* and *Trialeurodes ricini*) known to be vectors of plant geminiviruses (Idriss et al., 1997). The tomato yellow leaf curl virus, a geminivirus transmitted by whitefly, causes about 65% yield loss in tomato in Egypt (Anfoka et al., 2008).

The sweet-potato whitefly (*B. tabaci* Gennadius, Homoptera: Aleyrodidae) is a serious pest of many ornamental and greenhouse crops worldwide (Zhang et al., 2007). *T. ricini* Misra is broadly polyphagous but is most commonly associated with castor bean (*Ricinus communis* L.) and plant species belonging to the former Leguminosae (now Caesalpiniaceae, Papilionaceae, and Mimosaceae). In addition, it is a multivoltine species that is difficult to control and is also considered a serious tomato pest (Idriss et al., 1997).

In Egypt, chemical control has long been used as the primary method of managing whiteflies. However, this excessive dependence on insecticides has led to the development of insecticide-resistant whiteflies (Wu et al., 2010; Wang et al., 2011). Alternative control methods are required and interest is, therefore, increasing around the use of natural plant-derived oils as alternative pesticides to conventional and broad-spectrum toxicants.

Plant essential oils (EOs) may represent an alternative means of controlling whiteflies because they constitute a rich source of bioactive chemicals (Kim et al., 2005; Gusmão et al., 2013) that

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are active against specific target species, are not toxic to mammals and humans, and are potentially suitable for use in integrated pest management (Tare et al., 2004). Much effort has, therefore, been focused on plant EOs or phytochemicals as potential sources of commercial insect control agents. One potential approach involves the use of repellent semi-chemicals released from less preferred plants as behavior-modifying stimuli to manipulate the distribution of insect pests on host plants (Chamberlain et al., 2006; Cook et al., 2007). Managing insect pests using intercropping with less preferred plants has been successfully employed for various crops in Africa (Cook et al., 2007; Khan et al., 2008).

The chemical components of EOs have been shown to possess insecticidal and repellent properties (Spitzer, 2004; Chopa et al., 2006; Zandi-Sohani et al., 2012). Some isolated and specific compounds from crude extracts or plant EOs (mainly belonging to Apiaceae, Lamiaceae, Lauraceae, and Myrtaceae) and their components have insecticidal activity and can be used to fumigate against many pests like *Tribolium castaneum* Herbst, *Rhyzopertha dominica*, *Callosobruchus maculatus* Fabricus, *Sitophilus oryzae*, *S. zeamais*, *Corcyra cephalonica,* and *Sitotroga cerealella* (Rajendran and Sriranjini, 2008; Zandi-Sohani et al., 2012; Cansian et al., 2015).

Compounds such as α-pinene, α-phellandrene, β-phellandrene, and limonene are the most abundant components of the EO extracted from *Schinus terebinthifolius* (Périno-Issartier et al., 2010; Richter et al., 2010). EOs and their constituents from *Eucalyptus* have larvicidal activity against two mosquito species, *Aedes aegypti* (Linnaeus in Hasselquist, 1762) and *Aedes albopictus* (Skuse, 1894) (Cheng et al., 2009), and against *C. maculatus* (Coleoptera: Bruchidae) (Brito et al., 2006). Furthermore, repellent effects of EOs from various *Eucalyptus* species have been reported against *Phlebotomus papatasi* (Yaghoobi-Ershadi et al., 2006). α-Citronellal, the main component of *Eucalyptus citriodora* (*Corymbia citriodora*) oil (Maciel et al., 2010), and 1,8-cineole or eucalyptol in *E. globulus* (Chagas et al., 2002) were considered responsible for their acaricidal action. The attraction percentage of *Zabrotes subfasciatus* (Boheman) adults was reduced in grains of *Phaseolus vulgaris* L. treated with *C. citriodora* oil (de França et al., 2012).

The aim of this study was, therefore, to investigate the repellent and insecticidal potential of EOs from *S. terebinthifolius* fruit and *C. citriodora* leaves on two whitefly species, *B. tabaci* and *T. ricini,* under both laboratory and greenhouse conditions. The use of these EOs represents an alternative method of controlling this deleterious pest through suitable integrated pest management programs.

2. Materials and methods

2.1. Tomato culture of B. tabaci

B. tabaci adults from the laboratory tobacco culture were reared on tomato plants *Solanum lycopersicum* L. (Solanaceae) since 2000 in greenhouses at 25 ± 7 °C, 65 ± 5% relative humidity, and under natural light conditions.

2.2. Field strain of T. ricini

The *T. ricini* whiteflies were collected from the infested castor fields in Hagar Enwateia, Alexandria, Egypt. Puparia were identified as *T. ricini* according to the method of Martin et al. (2000).

2.3. Extraction of EOs

EOs from *S. terebinthifolius* fruits and *C. citriodora* leaves were extracted and used to investigate their olfactory and insecticidal effects on *B. tabaci* and *T. ricini*. The plants were collected in November 2014 from Antoniades Gardens, Alexandria, Egypt (*S. terebinthifolius* fruit) and from a plantation located on the Alexandria-Cairo desert road (Albostan area), Alexandria, Egypt (*C. citriodora* leaves). The plants were kindly identified by Prof. Ahmed A.A. El-Settawy (Head of Forestry and Wood Technology Department) and vouchered (No. Zidan00311 and Zidan00312 for *S. terebinthifolius* and *C. citriodora*, respectively) at the Division of Forestry and Wood Technology, Alexandria University.

For both *S. terebinthifolius* fruit and *E. citriodora* leaves, 100 g of tissue was loaded in a 2-L flask that was then ¾ filled with distilled water. The flask was connected to the Clevenger apparatus and condenser and the hydro-distillation was conducted for 3 h under heating (Salem et al., 2013). The oil was dried over anhydrous sodium sulfate and measured with respect to the initial fresh weight (1.5 and 3.15 mL 100 g^{-1} fresh weight from *S. terebinthifolius* fruit and *E. citriodora* leaves, respectively). The oil was kept dry in sealed Eppendorf tubes and stored at 4 °C before chemical analysis.

2.4. GC/MS analysis of the EOs

A Trace GC Ultra/Mass spectrophotometer ISQ (Thermo Scientific) instrument equipped with a flame ionization detector and a DB-5 narrow bore column (length 10 m × 0.1 mm ID, 0.17 μm film thickness; Agilent, Palo Alto, CA, USA) was used. Helium was used as the carrier gas (flow rate of 1 mL min^{-1}) and the oven temperature program was 45–165 °C (4 °C min^{-1}) and 165–280 °C (15 °C min^{-1}) with post run (off) at 280 °C. Samples (1 μL) were injected at 250 °C with a split/split-less injector (50:1 split ratio) in the splitless mode flow with 10 mL min^{-1}. The GC–MS was equipped with a ZB-5MS Zebron capillary column (length 30 m × 0.25 mm ID, 0.25 μm film thickness; Agilent). Helium (average velocity 39 cm s^{-1}) was used as the carrier gas and the oven temperature was held at 45 °C for 2 min then increased from 45 to 165 °C (4 °C min^{-1}) and 165–280 °C (15 °C min^{-1}). All mass spectra were recorded in the electron impact ionization at 70 electron volts. The mass spectrometer was scanned from *m/z* 50–500 at five scans per second. Peak area percent was used to obtain quantitative data using the GC with HP-ChemStation software (Agilent Technologies) without correction factors. Identification of the constituents was performed based on an MS library search (Wiley/NIST, 2008).

2.5. The olfaction response of B. tabaci and T. ricini

The olfactometer used was specially developed and devised for olfaction studies using *B. tabaci* whitefly adults. The olfactometer is also likely to be suitable for the associated whitefly *T. ricini* given similar miniature size, fragility, and behavior to light and geotropism of this insect (El-Meniawi et al., 2005).

The olfactometer comprised two identical sets of successive series of interchangeable units for treatment and control. It was connected to a glass water suction pump at one end and a suitable velometer at the other. Different units of the apparatus were fixed in place using suitable stands and connected to each other by fitted rubber tubes and rubber bands. Two incandescent lamps were placed on the top of the apparatus stands (Fig. 1).

The effectiveness of 0.01, 0.05, 0.1, 0.5, and 1% concentrations of each oil on the olfaction response of *B. tabaci* and *T. ricini* adults was checked. A piece of Whatman filter paper No. 1 (1.5 cm long and 0.5 cm width) was impregnated with each concentration of the tested EOs or with distilled water (DW) containing 0.01% triton X-100 as a control then introduced into the treatment and control scent traps in the olfactometer. Subsequently, twenty *B. tabaci* adults of both sexes were quickly and almost simultaneously introduced into each of the treatment and control exposure chambers. After ensuring the tight closure of all glass parts, covers, and taps, the lower taps of the aeration units were opened and the upper taps were closed. In this way, the fresh air current passing through each test chamber was replaced with another current that first