

## **Fumigant and Contact Toxicity and Oviposition Deterrent Effects of Plant Essential Oils on *Bemisia tabaci* (Hemiptera: Aleyrodidae)**

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# Fumigant and contact toxicity and oviposition deterrent effects of plant essential oils on (Hemiptera: Aleyrodidae)

Tufail Ahmed Wagan, Yueping He, Wanlun Cai, Jing Zhao, and Hongxia Hua\*

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## Abstract

Ethanol-extracted essential oils from sweet fag *Schot* (Acoraceae), cowparsnip *Diels* (Apiaceae), and wild asparagus *(Blume)* Miq. (Stemonaceae) were examined for their contact and fumigant toxicity and oviposition deterrent potential against *(Gennadius)* (Hemiptera: Aleyrodidae) under laboratory and greenhouse conditions during Oct to Dec 2015. To determine fumigant toxicity, adult whiteflies were tested in airtight glass jars containing essential oil on filter paper. Mortality rates were recorded after 2, 4, 6, and 8 h of exposure. Essential oil from *was the strongest toxicant*, with mortality rates of 20.4, 37.1, 73.3, and 98.8%, respectively, followed by *To test contact toxicity*, females were released in a cage containing tomato leaves treated with essential oil in the laboratory, and females were released in a cage containing tomato plants sprayed with essential oil in the greenhouse. Mortality rates were examined after 6, 12, 18, and 24 h in the laboratory and after 24 and 48 h in the greenhouse. Leaves were examined for oviposition immediately after the last recording. Essential oils from *showed the most insecticidal and ant-oviposition activity for all recording times* in both the laboratory (41.3, 56.9, 85.6, and 95.6% mortality, respectively) and the greenhouse (58.3 and 80.8% mortality, respectively), followed by *. Based on our study*, all 3 essential oils possess contact and fumigant toxicity and ant-oviposition properties against female whiteflies.

Key Words: tomato whitefly; ant-oviposition activity; laboratory; greenhouse

## Resumen

*Schot* (Acoraceae), vaca chirivía *Diels* (Apiaceae) y el espárrago silvestre *(Blume)* Miq. (Stemonaceae) para su toxicidad de contacto, su efecto fumigante y su potencial de disuadir la oviposición de *(Gennadius)* (Hemiptera: Aleyrodidae) en condiciones de laboratorio e invernadero desde octubre hasta diciembre del 2015. Para determinar la toxicidad como fumigante, adultos de la mosca blanca fueron probados en frascos de vidrio herméticos que contine el aceite esencial sobre papel de filtro. Las tasas de mortalidad se registraron a 2, 4, 6, y 8 horas de la exposición. El aceite esencial de *fue el tóxico más fuerte*, con tasas de mortalidad del 20,4, 37,1, 73,3 y 98,8%, respectivamente, seguido de *y Para la prueba de toxicidad por contacto*, las hembras fueron liberadas en una jaula que contine las hojas de tomate tratadas con el aceite esencial en el laboratorio, y las hembras fueron liberadas en una jaula con plantas de tomate rociadas con el aceite esencial en el invernadero. Se examinaron las tasas de mortalidad después de 6, 12, 18, y 24 horas en el laboratorio y después de 24 y 48 horas en el invernadero. Las hojas fueron examinadas para la oviposición inmediatamente después del último registro. Los aceites esenciales de *mostraron la mayor actividad insecticida y ant-oviposición para todos los tiempos de registro*, tanto en el laboratorio (41.3, 56.9, 85.6, y 95.6% de mortalidad, respectivamente) y el efecto invernadero (el 58,3 y el 80,8% de mortalidad, respectivamente), seguido por *y Basado en nuestro estudio*, los 3 aceites esenciales poseen propiedades de contacto y fumigante toxicidad y ant-oviposición contra las hembras de moscas blancas.

Palabras Clave: mosca blanca de tomate; actividad ant-oviposición; laboratorio; invernadero

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The silverleaf whitefly, *Gennadius* (Homoptera: Aleyrodidae), is a serious pest of agricultural crops and ornamental plants in fields and greenhouses throughout the World (Zhang et al. 2007). Both adults and nymphs feed on phloem, resulting in chlorosis in green plants (Cohen et al. 1998). They also excrete honeydew, which promotes the growth of sooty mould and disturbs normal photosynthesis. Indirectly, adults transmit viruses such as Melon yellows virus (MYV) and Tomato yellow leaf curl virus (TYLCV) (Nuez et al. 1999).

The presence of a waxy layer on the whitefly's body resists chemical insecticides penetration (James 2003), which makes it difficult to achieve

effective control. Nevertheless, irrational applications of chemical insecticides are widely used in open fields and greenhouses while managing whitefly infestations. Excessive application of synthetic insecticides leads to several problems in the environment, besides causing resistance in the development stages of pests (Palumbo et al. 2001). Furthermore, natural enemies of *suffer* due to frequent pesticide applications (Gonzalez-Zamora et al. 2004), which limits the ability of these natural enemies to manage heavy whitefly infestations. Thus, there is an urgent need to develop effective control alternatives that are environmentally friendly and harmless to humans and other non-target organisms.

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## Results

### LABORATORY EXPERIMENTS

#### Contact Toxicity

The insecticidal activity of the essential oils of *Origanum onites* and *Origanum graveolens* were tested against adult females of *A. gambiae*. The data indicate that all of the essential oils showed contact toxicity to *A. gambiae* during all experimental periods in the laboratory test. Among the tested oils, *Origanum graveolens* oil had the highest toxicity level at 12, 18, and 24 h of exposure, causing mortality rates of 56.9%, 85.6%, and 95.6%, respectively (Table 1). Compared with *Origanum graveolens* oil, essential oil of *Origanum onites* showed similar contact toxicity at 6 h of exposure (causing 43.1% mortality), but its toxicity was reduced and maintained at the second highest toxicity level at 12, 18, and 24 h of exposure, causing 47.5, 63.8, and 69.4% mortality, respectively. Compared with the other 2 oils, essential oil of *Origanum graveolens* had the highest toxicity level at all observation times, with mortality rates ranging from 31.3% at 6 h of exposure to 51.9% at 24 h (Table 1). Mortality rates in the controls were low and ranged from 1.9% at 6 h to 13.1% at 24 h (Table 1).

#### Fumigant Toxicity

Essential oil of *Origanum graveolens* had the strongest fumigant action among the tested oils at 4, 6, and 8 h of exposure, at which mortality rates of 61.3, 94.6, and 98.8% were recorded, respectively (Table 2). In the first cycle, *Origanum graveolens* oil caused 61.3% mortality at 4 h of exposure, 94.6% at 6 h, and 98.8% at 8 h. In the second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the tenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eleventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twelfth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirteenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fourteenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifteenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixteenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventeenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighteenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the nineteenth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twentieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the twenty-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirtieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the thirty-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fortieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the forty-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fiftieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the fifty-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixtieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the sixty-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the seventy-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eightieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the eighty-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninetieth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-first cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-second cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-third cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-fourth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-fifth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-sixth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-seventh cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-eighth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the ninety-ninth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h. In the hundredth cycle, mortality rates were 61.3% at 4 h, 94.6% at 6 h, and 98.8% at 8 h.

**Table 3.** Contact toxicity of plant essential oils determined as percentage of whitefly mortality after 24 and 48 h of exposure in the greenhouse experiment.

Treatment	Mortality (%)	
	24 h	48 h
Essential oil of <i>Adiantum species</i>	58.25 ± 3.47ab	80.75 ± 1.31a
Essential oil of <i>Adiantum species</i>	60.50 ± 2.32a	73.25 ± 2.03ab
Essential oil of <i>Adiantum species</i>	44.00 ± 5.86b	69.50 ± 1.95b
Control	12.50 ± 2.26c	17.50 ± 2.58c

Data are presented as mean ± SE of 8 replicates. Means within a column followed by the same letter are not significantly different. The mean numbers of adults were analyzed by 1-way ANOVA, using Tukey's HSD post-hoc test ( $p < 0.05$ ).

under laboratory and greenhouse conditions. Essential oil of *Adiantum species* showed the most lethal effect on whiteflies and had ant-oviposition activity at all times during both fumigant and contact experiments under laboratory and greenhouse conditions. Our findings support results from previous studies on *Adiantum species*. For instance, various plant parts of *Adiantum species* L. (Acoraceae) have been used in treatments such as insecticides, anti-bacterial medications, anti-fungal medications, and toxicants (Mital et al. 2009). Liu et al. (2013) examined the essential oil of *Adiantum species*, which showed contact toxicity at 92.21 µg/L and fumigant toxicity at 92.21 µg/L to *Psocoptera*: *Liposcelididae*. In our experiments, *Adiantum species* oil initially was similar in toxicity to the other 2 oils; however, its toxicity persisted over time and showed the maximum lethal effect in the end, eventually killing all the insects. This fluctuation may be caused by more chronic toxicity and less acute toxicity of the essential oil of *Adiantum species*.

The essential oil of *Adiantum species* showed insecticidal and ant-oviposition activity in all experiments. The maximum lethal effects were recorded at 73.3 and 83.8% whitefly mortality in contact and fumigant tests, respectively. Previous studies clearly indicate the toxic effects of *Adiantum species* plant parts. Most members of the genus *Adiantum species* contain furanocoumarins and are known to be insect repellents that suppress the growth of several insect species (Moore & Debboun 2006). Essential oils from *Adiantum species* are ingredients of various commercially available insecticides, and they can be used as safe fumigants for controlling *Adiantum species* (Ebadollahi & Ashouri 2011). Plants of the genus *Adiantum species* can have toxic effects on humans and other organisms; if the sap comes in contact with skin, it can cause severe phytophotodermatitis (Wikipedia 2016). In our experiment, essential oil from *Adiantum species* showed more acute and less chronic toxicity, and it was more effective upon contact than oil of *Adiantum species*. Its insecticidal properties and ant-oviposition activity shown in this study prove its potential as an insecticide ingredient against whiteflies.

**Table 4.** Effect of plant essential oils on whitefly oviposition determined after 24 and 48 h of exposure in the laboratory and greenhouse experiments.

Treatment	Number of eggs deposited		
	laboratory	greenhouse	field
Essential oil of <i>Adiantum species</i>	7.00 ± 0.53c	10.38 ± 1.00b	14.25 ± 0.92b
Essential oil of <i>Adiantum species</i>	7.25 ± 0.45c	17.12 ± 0.95b	19.50 ± 1.43b
Essential oil of <i>Adiantum species</i>	12.62 ± 0.46b	12.87 ± 1.01b	15.75 ± 1.25b
Control	28.37 ± 2.34a	35.75 ± 3.70a	46.13 ± 3.87a

Data are presented as mean ± SE of 8 replicates. Means within a column followed by the same letter are not significantly different. The mean numbers of eggs were analyzed by 1-way ANOVA, using Tukey's HSD post-hoc test ( $p < 0.05$ ).

The *Adiantum species* essential oil maintained fumigant and contact toxicity and ant-oviposition activity at all times. Previous research has also revealed its insecticidal activity. *Adiantum species* is one of the original plants in the Chinese Pharmacopoeia. As a traditional Chinese medicine, it has been used as an ant-tussive and an insecticidal agent (Greger 2006). Keys (1976) states that *Adiantum species* tubers contain an alkaloid called stemonine, which is toxic and strongly effective against *Adiantum species* (De Geer), *Adiantum species* (De Geer) (Pht raptera: Pediculidae), and *Adiantum species* (L.) (Pht raptera: Pht ridae) without causing irritation or toxicity to those handling the tubers. In our experiments, essential oil from *Adiantum species* showed more acute and less chronic toxicity similar to essential oil from *Adiantum species*. Regarding previous findings and results from our study, the lethal and ant-oviposition effects of *Adiantum species* essential oil on whiteflies support its usefulness as an insecticide.

We here report for the first time that essential oils from *Adiantum species* have contact and fumigant toxicity and oviposition deterrent properties against *Adiantum species*. We determined that essential oil from *Adiantum species* possessed the strongest toxicity—followed by oils of *Adiantum species*—in laboratory and greenhouse experiments. Furthermore, all 3 essential oils significantly reduced oviposition in all experiments. These essential oils do not persist in nature, and no detrimental effects were found in the treated plants; therefore, it could be said that these essential oils are eco-friendly and could be used in pest management programs. Further research is needed on the action of individual chemical constituents under laboratory and greenhouse conditions.

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References Cited

Cohen AC, Chu CC, Henneberry TJ, Freeman T, Nelson D, Buckner J, Margosan D, Vail P, Aung LH. 1998. Feeding biology of the silverleaf whitefly (Homoptera: Aleyrodidae). Chinese Journal of Entomology 18: 65-82.

Ebadollahi A, Ashouri S. 2011. Toxicity of essential oils isolated from *Adiantum species* L., *Adiantum species* L. and *Adiantum species* Desf. against adults of *Adiantum species* (Hübner) (Lepidoptera: Pyralidae) in Islamic Republic of Iran. Ecologia Balkanica 2: 41-48.

Gonzalez-Zamora JE, Leira D, Bellido MJ, Avilla C. 2004. Evaluation of the effect of different insecticides on the survival and capacity of *Adiantum species* Mercet to control *Adiantum species* (Gennadius) populations. Crop Protection 23: 611-618.

Greger H. 2006. Structural relationships, distribution and biological activities of *Adiantum species* alkaloids. Planta Medica 72: 99-113.

Hjorth AB, Christophersen C, Hausen BM, Menne T. 1997. Occupational allergic contact dermatitis from carnosol, a naturally-occurring compound present in rosemary. Contact Dermatitis 37: 99-100.

Isman MB. 2000. Plant essential oils for pest and disease management. Crop Protection 19: 603-608.

James RR. 2003. Combining azadirachtin and *Adiantum species* (Deuteromycota: Hyphomycetes) to control *Adiantum species* (Homoptera: Aleyrodidae). Journal of Economic Entomology 96: 25-30.

Keys D. 1976. Chinese Herbs—Their Botany, Chemistry and Pharmacodynamics. (1990 in paperback) Charles E. Tuttle, North Clarendon, Vermont. ISBN

Liu XC, Li GZ, Zhi LL, Shu SD. 2013. Identification of insecticidal constituents of the essential oil of *Adiantum species* rhizomes against *Adiantum species* Badonnel. Molecules 18: 5684-5696.

Mital N, Ginnwal HS, Varshney VK. 2009. Pharmaceutical and biotechnological potential of *Adiantum species* Linn.: an indigenous highly valued medicinal plant species. Pharmacognosy Reviews 3: 93-103.

# Wagan et al.: Effects of plant essential oils on *Trialeurodes vaporariorum*

- Moore SJ, Debboun M. 2006. The history of insect repellents. pp. 3–30. Debboun M, Frances SP, Strickman D [eds.], *Insect Repellents: Principles, Methods, and Use*. CRC Press, Boca Raton, Florida.
- Nuez F, Pico B, Iglesias A, Esteva J, Juarez M. 1999. Genetics of melon yellows virus resistance derived from *Trialeurodes vaporariorum* ssp. *Trialeurodes vaporariorum*. *European Journal of Plant Pathology* 105: 453–464.
- Palumbo JC, Horowitz AR, Prabhaker N. 2001. Insecticidal control and resistance management for *Trialeurodes vaporariorum*. *Crop Protection* 20: 739–765.
- Regnault-Roger C, Vincent C, Amason JT. 2012. Essential oils in insect control: low-risk products in a high-stakes world. *Annual Review of Entomology* 57: 405–424.
- Su YP, Yang CJ, Hua HX, Cai WL, Lin YJ. 2009. Bioactivities of ethanol extracts from thirteen plants against *Trialeurodes vaporariorum* (Stål). *Chinese Agricultural Science Bulletin* 25: 198–202.
- Wikipedia. 2016. The free encyclopedia: *Trialeurodes vaporariorum* plant, [https://en.wikipedia.org/wiki/Heracleum\\_\(plant\)#cite\\_ref-1](https://en.wikipedia.org/wiki/Heracleum_(plant)#cite_ref-1) (last accessed 9 May 2016).
- Yao YJ, Liang YY, Wang LQ, Zhang W, Yang CJ, Lin YJ, Hua HX. 2011. Control effect of extract and compound of *Trialeurodes vaporariorum* ssp. *Trialeurodes vaporariorum*. *Chinese Journal of Applied Entomology* 48: 463–467.
- Zhang GF, Lü ZC, Wan FH. 2007. Detection of *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) remains in predator guts using a sequence-characterized amplified region marker. *Entomologia Experimentalis et Applicata* 123: 81–90.