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Original article (Orijinal araştırma)

Toxicities of different essential oils to *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) and *Acanthoscelides obtectus* (Say, 1831) (Coleoptera: Bruchidae) adults

Farklı uçucu yağların *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) ve *Acanthoscelides obtectus* (Say, 1831) (Coleoptera: Bruchidae) erginlerine zehir etkileri

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Abstract

In this study, the toxicities of plant essential oils of *Artemisia absinthium* L., *Seriphidium santonicum* (L.) Soják, *Seriphidium spicigerum* (K. Koch) Poljakov and *Achillea santolinoides* Lag. (Asteraceae) to two spotted spider mite, *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) and bean weevil, *Acanthoscelides obtectus* (Say, 1831) (Coleoptera: Bruchidae) adults at 10, 15 and 20 µL/Petri dish were investigated. Tests (contact effect for *T. urticae* and fumigant effect for *A. obtectus*) were conducted at 26±1°C, 70±5% RH and 16:8 h L:D photoperiod. Mortality varied depending on plant essential oil. While the mortalities were recorded between 23 and 100% for *T. urticae*, they were between 45 and 100% for *A. obtectus.* After 72 h, when LD_{50} and LC_{50} values are taken into consideration, the most toxic plant essential oil was *A. santolinoides* (7.8 µL/mite for LD_{50}) oil for *T. urticae*. The most toxic plant essential oil after 72 h was *A. santolinoides* (0.001 µL/insect) oil on *A. obtectus* adults. These results showed that the plant essential oils derived from *A. absinthium, S. santonicum*, *S. spicigerum* and *A. santolinoides* may be among one of the most promising alternative methods to control *T. urticae* and *A. obtectus* adults.

Keywords: *Acanthoscelides obtectus,* essential oil, *Tetranychus urticae*, toxicity

Öz

Bu çalışmada, *Artemisia absinthium* L., *Seriphidium santonicum* (L.) Soják, *Seriphidium spicigerum* (K.Koch) Poljakov ve *Achillea santolinoides* Lag (Asteraceae) bitki uçucu yağlarının 10, 15 ve 20 µL/Petri dozlarında, ikinoktalı kırmızıörümcek, *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) ve fasulye tohum böceği, *Acanthoscelides obtectus* (Say, 1831) (Coleoptera: Bruchidae) erginleri üzerindeki zehir etkileri araştırılmıştır. Testler (*T. urticae* için kontakt etki ve *A. obtectus* için fumigant etki) 26±1°C, %70±5 RH ve 16:8 h (A:K ışık ortamında) laboratuvar şartlarında yürütülmüştür. Ölüm oranları, uçucu yağlara bağlı olarak farklılık göstermiştir. Bu ölümler *T. urticae* erginleri için %23 ile %100 arasında kaydedilirken, *A. obtectus* erginleri için ise %45 ile %100 arasında bulunmuştur. Uygulamanın 72 saatinden sonra, LD_{50} ve LC_{50} değerleri dikkate alındığında, *T. urticae* için en zehir etkili uçucu yağ olarak *A. santolinoides* (7.8 µL/akar LD_{50}) yağı tespit edilmiştir. Aynı süre içinde, *A. obtectus* üzerinde en fazla zehir etkisi ise *A. santolinoides* (0.001 µL/böcek) yağı için kaydedilmiştir. Bu sonuçlar, *A. absinthium, S. santonicum*, *S. spicigerum* ve *A. santolinoides* bitkilerinden elde edilen uçucu yağların, *T. urticae* ve *A. obtectus* erginlerini kontrol etmek için en umut verici alternatif metotlardan birisi arasında olabileceğini göstermektedir.

Anahtar sözcükler: *Acanthoscelides obtectus,* uçucu yağ, *Tetranychus urticae*, toksisite

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Introduction

Two spotted spider mite, *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae), is an important pest on different crops such as bean, cucumber, eggplant, pepper, strawberry, apple, cotton, jute, tea and various ornamental plants all over the world. It is a polyphagous pest and may cause serious damage to host plants by feeding with leaves and fruits (Jeppson et al., 1975; Zhang, 2003). It can reduce functional leaf surface and cause yellowing, crinkling and twisting of leaves by inserting its stylet into host leaves and absorbing the cell contents. Due to its serious damage, host plant leaves turn brown and die (Jeppson et al., 1975). Also, bean weevil, *Acanthoscelides obtectus* (Say, 1831) (Coleoptera: Bruchidae), is among the most threatening bruchid species of stored legumes seeds, leading to qualitative and quantitative losses, especially in the tropical and subtropical regions. The adults are not harmful. Its larvae feed in *Phaseolus vulgaris* L. (Fabaceae) seeds and lead to serious economic damage in conditions of low humidity. This pest can cause losses of up to 40% in stored legume grains and reduce their nutritional and commercial values (Cardona, 1989; Regnault-Roger & Hamraoui, 1995; Bailey, 2007). The larvae cause damage by continuous cycle feeding on both in storage and in legume seeds in the field (Labeyrie, 1962).

Insects and mites cause important economic losses in storage and in the field. So, there is a need for new insecticides and acaricides for use in both crops and stored products. The general alternatives to control this type of pests are chemical, biological, and physical control or their combinations. Many acaricides and insecticides have been used to prevent damage caused by these pests. However, these chemicals pose risks to environmental pollution, toxicities to other beneficial organisms, pest resistances, pesticide residues, directly toxicities to users and ozone depletion (Barnard et al., 1997; Nauen et al., 2001; Santos et al., 2009; Kumral et al., 2010). Therefore, health authorities are unwilling to allow synthetic chemicals due to their residues in food (Thaung & Collins, 1986). In addition, the new alternative control strategies are needed, because synthetic chemicals have a high toxic effect both on the environment and human health. These disadvantages of the synthetic chemicals have motivated a search for the alternative of the pesticides. For these reasons, studies in recent years have demonstrated that the natural products, such as plant extracts, have minimal effects to environment and the health of warm blooded organism compared to synthetic chemicals, and are preferred by growers to protect their crops from pest incursions (Arnason et al., 1989; Tapondjou et al., 2005). Among these plants derived compounds, plant essential oils are extracted from various parts such as flower, fruit, seed, leaf, stem, trunk, shoot and tuber of plants and known as friendly botanical pesticides for the safety of mammals and the environment. Given that they degrade in nature rapidly, they have almost no toxicity to warm blooded organisms when applied. Also, they are important for managing pest resistance (Daferera et al., 2000; Isman, 2000; Göktürk et al., 2017). However, most importantly are their effects, such as insecticidal, acaricidal, antifeedant and repellant, on many pests in the agricultural fields and stored products (Yıldırım et al., 2013).

Turkey has a high potential in terms of many aromatic and medicinal plant species as most of them are considered to be endemic (Davis, 1982; Baytop, 1999). Among them, genus *Artemisia* L. and *Achillea* L. are two valuable groups of the Asteraceae. This family has approximately 20,000 species belonging to 1,000 genera. The genus *Artemisia* has about 500 species in Asia, Europe and North America. Among them, *Artemisia absinthium* L., *Seriphidium santonicum* (L.) Sojak and *Seriphidium spicigerum* (K. Koch) Poljakov grow naturally in the different regions of Turkey. *Artemisia* species are known in Anatolia as *acı pelin*, *ak pelin*, *yavşan*, *deniz yavşanı* and *acı yavşan*. Most of them are vitally important because of their insecticidal, antifungal, antibacterial, allelopathic and other properties. The members of the genus contain high levels of plant essential oils and bitter substances that include flavone and pinene (Regnault-Roger & Hamraoui, 1995; Usanmaz Bozhüyük et al., 2016). The genus *Achillea* has almost 85 species, 42 species (20 species endemic) of them are found in Turkey (Davis, 1982; Baytop, 1999). *Achillea* species are called *civanperçemi*, *pireotu*, *yılan çiçeği*, *serviotu*, *kardeş kınası*, *ayvadene*, *kardeşkanı*, *kılıç otu*, *paspanos*, *pasvana* and *pesvana* in Anatolia. *Achillea santolinoides* (K. Koch) Lag. is grown naturally in almost all regions of Turkey, and has long been used for its therapeutically and aromatic (Davis, 1982; Kesdek et al., 2014).

Many scientific studies have been conducted on the toxicity of plant essential oils and their use as eco-friendly pesticides, and the vast majority of them have been accomplished (Aslan et al., 2004; Yıldırım et al., 2005; Tripathi et al., 2009; Ebadollahi et al., 2010; Regnault-Roger et al., 2012; Benelli et al., 2017; Üstüner et al., 2018). Some other notable studies were conducted with plant essential oils against mite and insect pests. Abdelgaleil & Badawy (2006) reported that the plant essential oil of *Mentha spicata* subsp. *condensata* (Briq.) Greuter & Burdet (syn. *Mentha microphylla* Koch) (Lamiaceae) gave from 56 to 100% mortality of *T. urticae* in a fumigation bioassay. Kumral et al. (2010) determined that seed and leaf extracts of the thorn apple (*Datura stramonium* L.) had acaricidal, repellent and oviposition deterrent activities on *T. urticae*. Fatemikia et al. (2014) found that *Elettaria cardamomum* L. (Zingiberaceae) plant essential oils had toxic effects on adults and eggs of *T. urticae*. Usanmaz et al. (2016) determined that the plant essential oils of *Seriphidium santonicum* (L.) Soják (syn. *Artemisia santonicum* L.), and *Seriphidium spicigerum* (K. Koch) Poljakov (syn. *Artemisia spicigera* K. Koch) caused high mortalities (85-100%) on the adults of *Callosobruchus maculatus* (Fabricius, 1775) (Coleoptera: Bruchidae). Fatemikia et al. (2017) found that *Ferula gummosa* Boiss. (Asteraceae) plant essential oils had high toxicity to eggs and adults of *T. urticae*. Also, they found that all tested concentrations of *F. gummosa* plant essential oils had oviposition activity and repellency of adults of *T. urticae*.

The genus *Artemisia* and *Achillea* species are common and abundant in natural areas of Turkey. *T. urticae* and *A. obtectus* are two important pests. While *T. urticae* causes significant damage to the different cultivated plants in the field, *A. obtectus* causes economic loses in the stored legume seeds. This study was planned to investigate which the tested plant essential oils are more effective on adults of the two pests. Therefore, the aim of the study was to determine acaricidal and insecticidal effects of the plant essential oils obtained from four plant species, *A. absinthium, S. santonicum, S. spicigerum* and *A. santolinoides* from different localities in Turkey, on *T. urticae* and *A. obtectus* adults under laboratory conditions.

Materials and Methods

Plant material and isolation of essential oils

Flowering stages of *A. absinthium, S. santonicum, S. spicigerum* and *A. santolinoides* were collected from different localities in Turkey between June 2016 and August 2017. The identification of plant materials was made by Prof. Dr. Yusuf Kaya, Department of Biology, Faculty of Art and Science, Atatürk University, Erzurum, Turkey. The voucher specimens of these plants have been deposited in the herbarium of Ataturk University, Erzurum, Turkey. Aerial parts of the plants were dried in shade before processing with a grinder. Then 500 g was hydrodistilled for 4 h using a Clevenger-type apparatus (Göktürk et al., 2017). Hydrodistillation of *A. absinthium, S. santonicum, S. spicigerum* and *A. santolinoides* yielded 0.6, 0.8 and 0.5% (w/w) of plant essential oil based on dried parts of the tested plants, respectively. The drying of the plant essential oils was done with anhydrous Na_2SO_4. The plant essential oils obtained were kept under N_2 in a closed glass bottle until needed, and then stored at 4°C during testing.

Insect and mite cultures

In this study, *T. urticae* and *A. obtectus* adults were collected from strawberry, *Fragaria ananassa* Rouzier (Rosaceae) plants without any pesticide exposure and infected bean, *Phaseolus vulgaris* L. (Fabaceae) seeds in a private storage facility, respectively, in (Fethiye, Muğla Province of Turkey in April and May of 2018. The bean seeds were purchased from a local market and kept in a deep-freezer at -15°C for 2 d to control any arthropod pests before use in bioassays. Then, *A. obtectus* adults were reared in 1 L jars containing cowpea seeds. The cultures were reared in the dark in a growth chamber at 26±1°C and 70±5% RH without exposure to any insecticide for several generations. *T. urticae* adults were reared on strawberry plants in the laboratory at 12-13% moisture content in a container (25 cm diameter x 30 cm high) under the same conditions.

Toxicity tests of the essential oils

To test the efficacy of the four plant essential oils against *T. urticae* and *A. obtectus* adults, assays were performed in Petri dishes (9 x 1.5 cm, 120 ml in volume). In order to determine the contact (for *T. urticae* adults) and fumigant effects (for *A. obtectus* adults), the plant essential oils were dissolved with ethanol (20, 30 and 40 µL/Petri dish) and sterile water (1 ml) solution (10%, v/v). The final concentrations of the treatments were 10, 15 and 20 µL/Petri dish. A filter paper was placed at the bottom of each Petri dish.

Contact toxicity test for *T. urticae* adults

To test the contact effects of the plant essential oils, 20 *T. urticae* adults were transferred from infested strawberry leaves to uninfested leaves using a thin brush in each Petri dish. To maintain the turgor of the uninfested leaves during experiments, the petioles of the leaves were placed in a piece of saturated cotton. The plant essential oils were then sprayed on *T. urticae* adults using a hand spray (Manual Potter Spray Tower-Burkard Scientific Limited, Uxbridge, UK). In this way, direct contact of the plant essential oils to *T. urticae* adults were ensured. Each Petri dish was covered with a lid, placed into the incubator, at 26±1°C, 70±5 RH and 16:8 h L:D photoperiod for 3 d. *T. urticae* adults on strawberry leaves were exposed separately the four plant essential oils. In order to determine mortalities at each exposure time, the number of dead *T. urticae* adults was counted under a microscope after 24, 48 and 72 h.

Fumigant toxicity test for *A. obtectus* adults

To test the fumigant toxicities of four plant essential oils on *A. obtectus* adults, the insect adults with 20 bean seeds were placed in Petri dishes. Three doses of the plant essential oils were applied with a pipette onto Whatman papers (No: 1; 2 x 2 cm) attached to underside of each Petri dish lid. Twenty *A. obtectus* adults were added to each Petri dish, which were covered with a lid and incubated for 3 d as above. The *A. obtectus* adults were feed with an appropriate amount of bean seed (1 seed/insect) during the tests. In order to determine mortalities for each exposure time, the number of dead adults was counted for *A. obtectus* adults under the microscope at 24, 48 and 72 h. A group treated with water and ethanol served as a negative control. Three different doses (10, 15 and 20 µL/Petri dish) of Malathion 65 EM (Koruma: malathion 650 g/l) were used as a positive control. All test procedures were performed under the same conditions as the cultures and each test was repeated three times.

Data analysis

To determine whether there was a statistically significant difference between the results obtained, Two-way analysis of variance was performed using SPSS (Statistical Package for Social Sciences 17.0). The differences between means were determined with Duncan's multiple range test. Lethal dose and Lethal concentration (LD_{50} and LD_{90}; LC_{50} and LC_{90}) values after 24, 48 and 72 h were calculated using the Finney method (Finney, 1971). To determine LC and LD values at 95% confidence limits EPA Probit Analysis Program was used. The results showed significant differences at $P < 0.05$ levels.

Results and Discussion

The results of the study are summarized in Tables 1 and 3. The plant essential oils gave different mortality rates and there are statistical differences between them. When the mortality rates of these plant essential oils were compared for 24 h exposure, it was found that there were statistical differences between the treatments for each pest. The highest mortality rate (100%) was with 15 and 20 µL/Petri dish of *A. santolinoides* oil with *T. urticae* adults. The lowest mortality rate (23%) was with 10 µL/Petri dish of *A. absinthium* oil (Table 1). Similarly, when the mortality rates of all doses of these plant essential oils were compared for 48 h exposure, the highest mortality (100%) was with 20 µL/Petri dish of *S. santonicum* and at 10, 15 and 20 µL/Petri dish of *A. santolinoides* oils with *T. urticae* adults, whereas the lowest mortality (55%) was with 10 µL/Petri dish of *A. absinthium* oil (Tables 1 & 3). However, after 48 h, the highest mortality

(97%) was with 20 µL/Petri dish of *A. absinthium* oil with *A. obtectus* adults. The lowest effect (78%) was observed at 10 µL/Petri dish of *S. santonicum* oil for this pest. As a parallel to these, when the mortality rates of 10, 15 and 20 µL/Petri dish caused by four plant essential oils at the end of 72 h were compared, the highest mortality rate (100%) was for *S. santonicum, A. santolinoides* and *S. spicigerum* plant essential oils with *T. urticae* adults. Also, 100% mortality was recorded with 20 µL/Petri dish of *A. absinthium* oil, but it was 90% and 98% with 10 and 15 µL/Petri dish of *A. absinthium* oil, respectively. The lowest mortality effect (90%) was with 10 µL/Petri dish of *A. absinthium* oil after 72 h with *T. urticae* adults. However, after 72 h, the mortality was more than 95% at 10, 15 and 20 µL/Petri dish for all plant essential oils with *A. obtectus* adults (Tables 1 & 3). Also, the toxicities of the plant essential oils on *T. urticae* and *A. obtectus* adults increased with increasing dose and exposure time. Mortality of both pests were significantly different according to treatment dose and time (for *T. urticae* adults, $F_{15,164} = 87.3$, $P < 0.05$; and for *A. obtectus* adults $F_{15,164} = 81.5$, $P < 0.05$). One of the most widely used acaricide and insecticide for *T. urticae* (mite pests) and *A. obtectus* adults (stored product pests) is malathion 65 EM. In this study, 100% toxicity was obtained after 72 h with the highest dose of malathion dose (20 µL/Petri dish) (Tables 1 & 3).

Table 1. The contact toxicity results of multiple comparison with means and standard error of exposure times and doses of plant essential oils of four plant species with *T. urticae* adults

Treatment Essential oils	Dose (µL/Petri)	*Tetranychus urticae* mortality (%)[a]					
		Exposure time (h)[b]					
		24 h		48 h		72 h	
Artemisia absinthium	10	23±3.3	h	55±2.9	f	90.0±0.0	b
	15	32±3.3	gh	70±0.0	e	98±1.7	a
	20	42±1.7	ef	78±3.3	cd	100±0.0	a
Seriphidium santonicum	10	35±5.8	fg	78±1.7	cd	100±0.0	a
	15	63±4.4	d	98±1.7	ab	100±0.0	a
	20	93±4.4	ab	100±0.0	a	100±0.0	a
Seriphidium spicigerum	10	50±2.9	e	73±1.7	de	100±0.0	a
	15	78±4.4	c	80±2.9	c	100±0.0	a
	20	85±2.9	bc	93±3.3	b	100±0.0	a
Achillea santolinoides	10	82±1.7	c	100±0.0	a	100±0.0	a
	15	100±0.0	a	100±0.0	a	100±0.0	a
	20	100±0.0	a	100±0.0	a	100±0.0	a
Positive Control (Malathion 650 g/l)	10	100±0.0	a	100±0.0	a	100±0.0	a
	15	100±0.0	a	100±0.0	a	100±0.0	a
	20	100±0.0	a	100±0.0	a	100±0.0	a
Negative Control (Ethanol + Sterile water)	-	0±0.0	ı	0±0.0	g	2±1.4	c

[a] The values are mean±SE of three replicates, each set up with 20 adults;
[b] Exposure time values followed by the same letters within a column are not significantly different at P≤0.05.

When LD and LC values after 72 h treatment (LD_{50}, LD_{90} and LC_{50}, LC_{90}) of these plant essential oils were compared for their effects on *T. urticae* and *A. obtectus* adults, the most toxic plant essential oils based on LD_{50} and LD_{90} values were for *A. santolinoides* (7.8 µL/mite) and *S. spicigerum* (4.8 µL/mite) plant essential oils with *T. urticae* adults. However, the most toxic plant essential oils, based on LC_{50} and LC_{90}, after 72 h were with *A. santolinoides* (0.001 µL/insect) and *S. santonicum* (8.0 µL/insect) plant essential oils with *A. obtectus* adults. Similarly, the most toxic plant essential oil after 48 h, based on LD_{50} and LD_{90}, was with *A. santolinoides* plant essential oils (7.8 µL/mite and 10.0 µL/mite) with *T. urticae* adults, respectively. Also, the most toxic plant essential oils, based on LC_{50} and LC_{90}, after 48 h was with *A. santolinoides* (6.1 µL/insect and 19.7 µL/insect) plant essential oil with *A. obtectus* adults, and the most toxic plant essential oil after 24 h, based on LD_{50} and LD_{90}, was with *A. santolinoides* plant essential oil (9.4 µL/mite and 11.0 µL/mite) with *T. urticae* adults, respectively. After 24 h, the most toxic LC_{50} and LC_{90} values were with *A. absinthium* plant essential oil (15.7 µL/insect and 28.2 µL/insect) with *A. obtectus* adults. The lowest toxicity after 72 h, based on LD_{50} and LD_{90} values, was with *S. santonicum* and *A. absinthium* plant essential oils (336.9 µL/mite and 14.7 µL/mite) with *T. urticae*. The lowest toxicity after 72 h, based on LC_{50} and LC_{90}, was with *A. absinthium* and *S. spicigerum* (7.8 µL/insect) and *A. santolinoides*

(24.4 µL/insect) plant essential oils with *A. obtectus* adults, respectively (Tables 2 & 4). The lowest toxicity after 24 and 48 h, based on LC_{50} and LC_{90}, was with S*. spicigerum* and *A. santolinoides,* and *S. santonicum* plant essential oils with *A. obtectus*, respectively. The lowest toxicities after 24 and 48 h, based on LD_{50} and LD_{90}, were with *A. absinthium* and *S. spicigerum* plant essential oils with *T. urticae* adults, respectively. These results showed that the acaricidal and insecticidal activities increased with increasing dose and exposure time. All of the plant essential oils gave meaningful mortalities (Tables 1 to 4).

Table 2. Lethal dose (LD) values of plant essential oils of four plants with *T. urticae* adults

Essential oils	Time (h)	LD_{50}[a]	LD_{90}[b]	X^{2*}	Slope±SE	Probability
Artemisia absinthium	24	29.7	70.5	1.5	3.4±6.0	0.2
	48	9.9	34.9	1.2	2.3±2.8	0.6
	72	10.9	14.7	2.6	9.8±15.1	0.9
Seriphidium santonicum	24	15.4	20.0	6.5	11.3±3.2	0.4
	48	11.1	14.0	2.4	12.3±23.5	0.8
	72	336.9	14.4	8.0	0.9±7.2	1.0
Seriphidium spicigerum	24	9.9	23.0	1.8	3.5±3.2	0.5
	48	16.6	20.3	5.1	14.6±6.5	0.7
	72	19.9	4.8	6.3	2.1±4.5	1.0
Achillea santolinoides	24	9.4	11.0	0.2	19.8±42.8	0.8
	48	7.8	10.0	2.1	12.3±36.2	1.0
	72	7.8	10.0	2.1	12.3±36.2	1.0

[a,b] The lethal concentration give rise to 50 and 90% mortality after 24,48 and 72 h;
* Chi square rate.

Table 3. The fumigant toxicity results of multiple comparison with means and standard error of exposure times and doses of plant essential oils of four plant species with *A. obtectus* adults

Treatment Essential oils	Dose (µL/Petri)	*Acanthoscelides obtectus* mortality (%)[a] Exposure time (h)[b] 24 h		48 h		72 h	
Artemisia absinthium	10	48±4.4	hı	87±4.4	cde	98±1.7	a
	15	67±1.7	cd	93±1.7	efg	100±0.0	a
	20	82±1.7	b	97±1.9	ab	100±0.0	a
Seriphidium santonicum	10	50±32.9	ghı	78±1.7	f	95±2.9	a
	15	57±1.7	efg	83±1.7	ef	98±1.7	a
	20	72±1.7	c	92±1.7	bcd	100±0.0	a
Seriphidium spicigerum	10	45±2.9	I	85±2.9	def	98±1.7	a
	15	52±1.7	fgh	92±1.7	def	100±0.0	a
	20	58±1.7	ef	95±0 .0	ab	100±0.0	a
Achillea santolinoides	10	55±2.9	efgh	82±1.7	ef	100±0.0	a
	15	62±1.7	de	92±1.7	bcd	100±0.0	a
	20	67±1.7	cd	93±1.7	abc	100±0.0	a
Positive Control (Malathion 650 g/l)	10	100±0.0	a	100±0.0	a	100±0.0	a
	15	100±0.0	a	100±0.0	a	100±0.0	a
	20	100±0.0	a	100±0.0	a	100±0.0	a
Negative Control (Ethanol + Sterile water)	-	0±0.0	j	1.7±1.4	g	3±1.0	b

[a] The values are mean±SE of three replicates, each set up with 20 adults;
[b] Exposure time values followed by the same letters within a column are not significantly different at P≤0.05.

In a previous study, it was established that *A. absinthium* plant essential oil caused mortality from 71 to 100% at 10, 15 and 20 µL/Petri dish after 96 h exposure of *Leptinotarsa decemlineata* Say, 1824 (Coleoptera: Chrysomelidae) (Kesdek et al., 2015). Eight plant extracts caused mortalities between 9 and 96% on *Tetranychus cinnabarinus* (Boisduval, 1867) after 24 h (Chen & Dai, 2015). In the present study, *A. absinthium* plant essential oil caused mortality from 23 to 100% of *T. urticae* adults and 48 to 100% of *A. obtectus* adults. Topuz & Madanlar (2011) reported that *Mentha pulegium* L. (Lamiaceae)*, Foeniculum vulgare* Mill. (Apiaceae) and *Schinus molle* L. (Anacardiaceae) plant essential oils gave up to 50% mortality at 20 ml/l dose after 96 h in *T. cinnabarinus.* Kesdek et al. (2015) found that *Seriphidium santonicum* (L.) Sojak (syn. *Artemisia santonicum* L.) oil caused mortality between 7 and 100% in *L. decemlineata* adults. In another study, it was determined that *S. santonicum* (syn. *A. santonicum*) plant essential oil lead to mortalities between 20 and 98% in *C. maculatus* adults (Usanmaz Bozhüyük et al., 2016). In the present study, *S. santonicum* (syn. *A. santonicum*) oil caused mortality from 35 to 100% in *T. urticae* adults. These mortality rates ranged from 50 to 100% in *A. obtectus* adults. Similarly, *Seriphidium spicigerum* (K. Koch) Poljakov (syn. *Artemisia spicigera* (K. Koch) oil caused mortalities between 4 and 42% in *L. decemlineata* adults (Kesdek et al., 2015), and from 27 to 98% in *C. maculatus* (Usanmaz Bozhüyük et al., 2016). In the present study, the mortality rates in *T. urticae* adults ranged from 50 to 100% for *S. spicigerum* oil and between 45 to 100% in *A. obtectus* adults. In another study, *Achillea santoliniodes* (K. Koch) Lag. (syn. *Achillea wilhelmsii* K. Koch) plant essential oil caused mortality from 2 to 29% in *L. decemlineata* adults after 96 h (Kesdek et al., 2015). In the present study, *A. santoliniodes* plant essential oil caused mortalities between 82 and 100% in *T. urticae* adults, and from 55 to 100% in *A. obtectus* adults.

Table 4. Lethal concentration (LC) values of plant essential oils acquired from four plants with *A. obtectus* adults

Essential oils	Time (h)	LC_{50}[a]	LC_{90}[b]	X^2*	Slope±SE	Probability
Artemisia absinthium	24	15.7	28.2	1.3	5.0±5.2	0.5
	48	9.8	21.5	3.5	3.8±10.8	0.9
	72	7.8	10.0	2.1	12.3±36.2	10.0
Seriphidium santonicum	24	20.9	32.8	0.7	76.6±5.5	0.5
	48	17.6	26.5	0.9	7.3±8.9	0.8
	72	3.6	8.0	5.6	3.7±2.2	1.0
Seriphidium spicigerum	24	27.0	140.0	0.7	1.8±4.12	0.5
	48	7.7	22.3	1.2	2.8±9.1	0.9
	72	7.8	10.0	2.1	12.3±36.2	1.0
Achillea santolinoides	24	19.8	142.4	10.7	1.5±14.5	0.6
	48	6.1	19.7	1.5	2.5±2.1	0.8
	72	0.001	24.4	7.1	0.3±3.3	1.0

[a,b] The lethal concentration give rise to 50 and 90% mortality after 24,48 and 72 h;
* Chi square rate.

In conclusion, natural acaricides and insecticides are a suitable alternative to synthetic acaricides and insecticides due to their low mammalian toxicity, low environmental effects and worldwide acceptability. Therefore, their adoption will contribute to a reduction in the negative sides of synthetic chemicals, such as residues in food products, insect resistance and environmental pollution. In the present study, the results suggest that four plant essential oils have the potential for use in the control of *T. urticae* and *A. obtectus* adults. Among them, *S. spicigerum* and *A. santolinoides* plant essential oils were found to be more toxic against *T. urticae* adults, whereas *A. absinthium* and *A. santolinoides* plant essential oils were more effective against *A. obtectus* adults. Therefore, it is suggested that these plant essential oils be considered as potential new acaricides and insecticides for *T. urticae* and *A. obtectus*. However, further studies need to be conducted to evaluate the mode of action and cost-effectiveness of these plant essential oils in a wider range of pests in agricultural products and storage facilities.

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