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Research Article

Contact and fumigant toxicity of *Foeniculum vulgare* and *Citrus limon* essential oils against *Tetranychus turkestani* and its predator *Orius albidipennis*

Niloufar Faraji[1], Ali Asghar Seraj[1*], Fatemeh Yarahmadi[2] and Ali Rajabpour[2]

1. Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University, Ahvaz, Iran.
2. Department of plant protection, Faculty of Agriculture, Ramin Agriculture and Natural Resources University of Khouzestan, Ahvaz, Iran.

Abstract: *Tetranychus turkestani* is one of the most important pests of greenhouse plants in the southern provinces of Iran. Several benefits of using essential oils over chemical pesticides make them appropriate for IPM programs. Contact and fumigant toxicity of the essential oils of *Foeniculum vulgare* and *Citrus limon* against the spider mite and its predator, *Orius albidipennis* were investigated under laboratory conditions. Contact toxicity experiments were conducted at six concentrations, (0, 50, 100, 300, 800 and 2000 ppm) of each essential oil on the mature and immature life stages of the pest, and mortalities were recorded 72 h after exposure. In fumigant toxicity trials, LC_{50} values of the essential oils were determined on different developmental stages of *T. turkestani* and *O. albidipennis*. At 800 and 2000 ppm, both essential oils had high contact toxicity on the eggs, 2nd instar nymphs and adults of *T. turkestani*, while the same concentrations caused less mortality on *O. albidipennis*. No significant phytotoxicity of the essential oils was observed. The mortality rates of *T. turkestani* and *O. albidipennis* increased as concentration was increased. Also, the 2nd instar nymph of *T. turkestani* was more sensitive to contact application of the essential oils than other developmental stages. In the fumigant toxicity bioassay, LC_{50} values of the essential oil derived from *F. vulgare* on the egg, 2nd instar nymph and adult of *T. turkestani* were 16.08, 7.98 and 14.06, and the values for *C. limon* essential oil were 11.6, 9.86 and 11.52 $\mu l \times l^{-1}$air, respectively. The highest fumigant toxicity was observed against the 2nd instar nymphs of the mite. Fumigant toxicity of the essential oils was lower against *O. albidipennis* than against *T. turkestani*. This data suggests that the essential oils of these plants have the potential of being employed in the IPM programs of *T. turkestani* in greenhouse crops, especially cucumber.

Key words: Essential Oils, Contact toxicity, Fumigant toxicity, Phytotoxicity

Introduction

The spider mite, *Tetranychus turkestani* Ugarov & Nikolski (Acari; Tetranychidae) is one of the most important pests of greenhouse plants. This mite directly damages the chloroplast by sucking the leaf cells and causes indirect damage by decreasing photosynthesis (Zhang, 2003; Sohrabi, and Shishehbor, 2007). Pesticide application is the primary method to control *Tetranychus urticae*. However, there are problems associated with the use of pesticides for the control of this mite because populations

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develop resistance to acaricides and the chemicals leave residues on fruits (Wysoki, 1985). Concurrently, popular concerns about environmental effects and pesticide residues have resulted in political and economic pressures to reduce chemical pesticide application and use products that are less toxic and more environmentally safe (Pedigo, 2002). Biological control using predators and other natural enemies as well as the use of natural products to control pests, are important components of integrated pest management (IPM) programs (Weinzier and Henn, 1991). Species in the genus *Orius* (Hemiptera: Anthocoridae) are generalist predators that attack eggs and immature stages of various arthropods, or small soft-bodied adult arthropods, including spider mites (Reitz *et al.*, 2006). Among natural products, certain highly volatile essential oils control insect pests, particularly in confined environments such as greenhouses or granaries (Bakkali *et al.*, 2008). So, much effort has been focused on plant essential oils as suitable alternatives to synthetic pesticides owing to their generally reduced negative impacts on humans, beneficial insects and the environment (Bakkali *et al.*, 2008; Akhtar and Isman, 2012). Essential oils can be suitable alternatives to synthetic pesticides. Fumigant toxicity of essential oils derived from some plants, such as *Mentha pulegium* L. (Mozaffari *et al*., 2013), *Satureja hortensis* L., *Ocimum basilicum* L., *Thymus vulgaris* L. (Aslan *et al*., 2004), *Cymbopogon nardus* L., *Euggenia caryophyllata* Thunberg, *Eucalyptus citriodora* Hook and *Salvia officinalis* L. (Han *et al.,* 2010), has been investigated on *T. turkestanii*. Also, contact toxicities of *Rosmarinus officinalis* L. and *S. officinalis* essential oils have been recorded against the mite (Miresmailii *et al*., 2006). The integration of insecticide (or acaricide) and biological control is often critical to the success of an IPM program against arthropod pests (El-Wakil *et al*., 2012). One of the requirements of the IPM program is that different strategies should be compatible (Pedigo, 2002). Essential oils of Iranian native plants and their major constituents obtained from rich medical flora, offer an alternative source of insect management agents because of their availability, efficiency and safety to environment and non-target organisms (Ebadollahi, 2011). The present study aimed to investigate the contact and fumigant toxicities of *Foeniculum vulgare* Mill and *Citrus limon* L. essential oils against *T. turkestani* and its natural enemy, *O. albidipennis*, to possibly integrate them into the mite IPM program in greenhouses.

Materials and Methods

Rearing

Tetranychus turkestani

A colony of the spider mite was collected from Khuzestan´s cucumber greenhouses. The colony was reared on *Cucumis sativus* L. at 25 ± 1 °C, 60 ± 5% relative humidity and photoperiod of 16L: 8D (h) in an incubator. After colonization for 10 generations, the adult female mites were used for experiments.

Orius albidipennis

The laboratory colony of *O. albidipennis* was established with the bug adults collected from sunflower and corn plants at the experimental farm, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Iran. The colony was kept at 25 ± 2 ºC, 65 ± 5% RH and photoperiod of 16: 8 h (L: D). *O. albidipennis* was reared in transparent plexiglass cylindrical containers (7.5 cm diameter by 18 cm height). The containers had two ventilation holes (2 cm in diameter) covered with fine gauze. Each rearing container contained a piece of bean pod *Phaseulus vulgaris* L. as moisture source and oviposition substrate. Adults were fed with a mixture of sterile eggs of *Ephestia kuehniella* Zeller and dry corn pollen.

Plant materials

Fresh seeds of *F. vulgare* and fruits of *C. limon* were collected from Khuzestan Province, Iran. Seeds of fennel were subjected to hydrodistillation by a Clevenger apparatus for 3 h. The collected oil was dried over anhydrous sodium sulfate. Lemon essential oil was derived from fresh lemon peel by cold-pressed method

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and then the oil was separated from the crude extract by centrifugation (at 4000 rpm for 15 min) (Babazadeh Darjazi, 2014). The supernatant was dehydrated with anhydrous sodium sulfate for 24 h and then filtered. Prepared essential oils were stored in special black coating vials at 4 °C before tests.

All experiments were carried out in a germinator at 25 ± 2 °C, 65 ± 5% RH and photoperiod of 14:10 h (L: D) with adequate ventilation.

Bioassay for phytotoxicity experiments

The application of essential oils by contact tends to be phytotoxic to plants and may sometimes burn the leaves. Therefore, it is necessary to assess the doses that cause phytotoxic effects. The effects of the essential oils on greenhouse cucumber leaves were evaluated by a method described by Aslan *et al.* (2004). Cucumber leaves were sprayed with experimental concentrations and every burning symptoms that differed from the control (treated with distilled water + 0.18% Tensiofix IS as an adjuvant) was recorded after 72 h.

Contact toxicity bioassay

All trials were done in laboratory at 25 ± 2 °C, 65 ± 5% relative humidity and photoperiod of 14:10 h (L: D). Experiments were conducted in a completely randomized design with 8 replications and 20 insects or mites per replication.

Contact toxicity of essential oils on the spider mite (4 d-old eggs, 1 d-old 2nd instar nymphs and 2 d-old adults) was assessed based on the method of Yang *et al.* (2010). All developmental stages of *T. turkestani* were obtained by introducing adults (10 per plant) on leaves of greenhouse cucumber in cages (1cm diameter). After 24 h, the adults were removed, and allowed the eggs to develop to the experimental stages. Eggs (4 d old), 2nd instar nymphs (1 d old) and adults (2 d old) were obtained 5, 8 and 12 days after removing adults, respectively. The leaves for each stage were dipped in the prepared essential oils (50, 100, 300, 800 and 2000 ppm) + 0.18% Tensiofix IS (an adjuvant) and 0.18% Tensiofix IS (as control) for 5 seconds. These concentrations were selected after preliminary tests (Robertson *et al.*, 2007). Treated leaf was placed in an octagon dish 10 cm in diameter and 3.8 cm in height. To facilitate ventilation, a hole was made on top of the dishes (2.5 cm) and covered with fine gauze. Mortality was recorded after 48 h and was corrected by Abbott's formula. All experiments had eight replications.

The contact toxicity to *O. albidipennis* was performed according to IOBC. Four d-old eggs, 2 d-old 5th instar nymphs and 2 d-old adults were chosen for bioassay, based on standard methods proposed by IOBC (Hassan, 1985). All developmental stages of *O. albidipennis* were obtained by introducing adults (50 per plant) to fresh bean pod in the transparent Plexiglas cylindrical container. The bugs were fed with eggs of *E. kuehniella* and corn pollen. After 24 h, adults were removed, and the eggs on the bean pod were let to develop to appropriate stages. Four d-old eggs, 2 d-old 5th instar nymphs and 2 d-old adults were obtained after 6, 21 and 25 days respectively. The concentrations of the used essential oils solutions were similar to those used for *T. turkestani*. To investigate contact toxicities of the essential oils against egg, bean pods that carried eggs of *O. albidipennis* were dipped in each essential oil concentration for 5 seconds and the number of hatched eggs were recorded after 72 h. Leaf of cucumber was dipped in selected essential oil concentration for 5 seconds. When the leaf was dried, it was placed in the octagonal dish. Then, adults or 5th instar nymphs of the bug were introduced on the leaf and mortality was recorded after 48 h and was corrected by Abbott's formula (Abbott, 1925).

Fumigant toxicity bioassay

The fumigant toxicity of the essential oils was investigated based on Aslan *et al.* (2004), Choi *et al.* (2004), Yi *et al.* (2006) and Koschier and Sedy (2007). The bioassays were performed in an incubator at 25 ± 2 °C, 65 ± 5% relative humidity and aphotoperiod of 14:10 h (L: D). Experiments were conducted in a completely

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randomized design with 8 replications and 20 insects or mites per replication.

Different concentrations of 3.57, 5.71, 8.57, 14.28 and 21.43 µl × l^{-1}air were determined by preliminary tests (Robertson, 2007). Developmental stages and accessing to these stages were similar to the cases in contact toxicity of essential oils. To estimate LC_{50}, 20 individuals of each mite stage were transferred to the dorsal side of cucumber leaves (2 cm diameter) that were placed on four layers of wet (saturated with distilled water) filter paper (Whatman N°) in a petri dish using a soft paint brush and were allowed to settle for half an hour before being exposed to the essential oil. To prevent a direct contact between the mite and the tested oils, the desired oil quantities were applied on filter paper (7 × 5cm) fixed on the undersurface of the desiccator (7 L volume). Mortality was recorded 24 h after exposure and was corrected by Abbott's formula.

Every different stage of *O. albidipennis* was placed into a single rearing container containing bean pod, *E. kuehniella* eggs and corn pollen. Every container was entered to the desiccators which consisted of a determined concentration. Because the container's holes were covered with fine gauze, essential oil vapors could easily enter the container. The mortality was recorded after 24 h and was corrected by Abbott's formula (Abbott, 1925).

Data analysis

Mortality data was corrected by Abbott's formula (Abbott, 1925). Corrected mortality rates among concentrations of EOs applied on each developmental stage of the target species were compared first using one-way analysis of variance (ANOVA) and then by the Least Significant Difference (LSD) test. The data were arcsine transformed to meet the assumptions of normality. The transformed data were used in the analysis. Phytotoxicity percentages in various treatments were analyzed by the general linear model (GLM) procedure. For these data, a binomial error distribution with logit link function was used. Probit analysis was used to estimate LC_{50}. All analyses were performed by SAS software version 9.1.

Results

Phytotoxicity

At concentrations 2500 and 5000 ppm of both essential oils, the phytotoxicity of the cucumber leaves was significantly more than that of the control ($F = 256.6$; df = 2, 14; $P < 0.0001$. However, at 2000 ppm phytotoxicity symptoms were not significantly different from the control. Therefore the essential oils could be applied to greenhouse cucumbers at 2000 ppm (Table 1).

Table 1 Phytotoxicity percentages of *Citrus limon* and *Foeniculum vulgare* essential oils in greenhouse cucumber leaves.

Essential oils	Phytotoxicity (%)[1]		
	2000 ppm	2500 ppm	5000 ppm
C. limon	0c	6b	100a
F. vulgare	0c	4b	100a
Control	0a	0a	0a

[1] Means within a row followed by the same letters are not significantly different (LSD test, $P < 0.05$).

Contact toxicity

Mortality percentages of the mite at different life stages associated with different concentrations of *F. vulgare* and *C. limon* essential oils, are shown in Table 2. Significant differences were observed between the effects of different dosages of *C. limon* ($F = 826.71$; df = 4, 39; $P < 0.0001$) and *F. vulgare* ($F = 515.16$; df = 4, 39; $P < 0.0001$) essential oils. Moreover, the 2nd instar nymph of *T. turkestani* had a higher mortality rate compared with other developmental stages. The mortality of *T. turkestani* increased as concentrations of the essential oils were increased (Table 2).

The essential oils derived from *C. limon* and *F. vulgare* showed low contact toxicity against different stages of *O. albidipennis* (Table 3). The observed mortalities were significantly different in various essential oil concentrations

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(F = 739.51; df = 4, 39; $P < 0.0001$). Mortality rates in developmental stages of *O. albidipennis* were low, when concentrations of 50 and 100 ppm were applied.

Fumigant toxicity

The lethal concentration (LC_{50}) values of each essential oil are shown in Table 4. The lowest LC_{50} values were recorded against the nymphs, for lemon essential oil on *T. turkestani* (7.98 µl l^{-1}air) followed by fennel (9.86 µl l^{-1}air) (Table 4). Considering CL overlapping, LC_{50} values were significantly different for eggs, but did not differ for nymphs and adults for the two oils. For both essential oils, high fumigant toxicity was observed on the 2nd instar nymphs of the mite.

Essential oil derived from *C. limon* was more toxic than *F. vulgare* essential oil in fumigant application. The essential oils of *F. vulgare* and *C. limon* showed lower fumigant toxicity against *O. albidipennis* than *T. turkestani* (Table 5). LC50 values of both essential oils on the 5th instar nymph were lower than other tested life stages. Therefore, it can be concluded that the 5th instar nymph of *O. albidipennis* is more susceptibe to the essential oils than the adult and egg life stages.

Table 2 Contact mortality percentages of *Citrus limon* and *Foeniculum vulgare* essential oils on three developmental stages of *Tetranychus turkestani***.**

Concentration (ppm)	Mortality ± SE (%)[1]					
	Egg		2nd instar nymph		Adult	
	C. limon	*F. vulgare*	*C. limon*	*F. vulgare*	*C. limon*	*F. vulgare*
50	6.25 ± 0.46d*	5.60 ± 0.64d	1.95 ± 0.46e	2.37 ± 0.52e	5.60 ± 0.83d	5.60 ± 0.64d
100	9.35 ± 0.83a	0.76 ± 0.25d	2.14 ± 0.71d	3.25 ± 0.7d	8.10 ± 0.52d	5.60 ± 0.64d
300	9.35 ± 0.99a	21.85 ± 0.74c	40.40 ± 0.76c	31.25 ± 0.7c	30.00 ± 0.75c	22.50 ± 0.75c
800	6.85 ± 0.52c	35.60 ± 0.64b	57.45 ± 0.75b	46.25 ± 0.7b	1.84 ± 0.24b	53.75 ± 0.7b
2000	8.75 ± 0.83b	69.35 ± 0.83a	88.35 ± 0.76a	76.85 ± 0.74a	17.62 ± 0.52a	73.75 ± 0.7a

[1] Means within a column followed by the same letters are not significantly different (LSD test, $P < 0.05$).

Table 3 Contact mortality percentages of *Citrus limon* and *Foeniculum vulgare* essential oils on three developmental stages of *Orius albidipennis*

Concentration (ppm)	Mortality ± SE (%)[1]					
	Egg		5nd instar nymph		Adult	
	C. limon	*F. vulgare*	*C. limon*	*F. vulgare*	*C. limon*	*F. vulgare*
50	1.25 ± 0.46c	5.60 ± 0.52c	1.85 ± 0.52c	6.25 ± 0.46d	3.10 ± 0.52c	3.10 ± 0.52d
100	2.75 ± 0.53c	6.85 ± 0.64c	2.50 ± 0.53c	8.10 ± 0.52d	3.75 ± 0.70bc	3.75 ± 0.46d
300	3.10 ± 0.52c	8.10 ± 0.52c	3.40 ± 0.46c	11.25 ± 0.46c	6.25 ± 0.46b	6.85 ± 0.52c
800	8.10 ± 0.74b	14.35 ± 0.64b	11.85 ± 0.74b	19.35 ± 0.64b	11.25 ± 0.46b	13.75 ± 0.70b
2000	26.25 ± 0.70a	37.50 ± 0.75a	41.25 ± 0.70a	52.5 ± 0.75a	33.75 ± 0.70a	45.00 ± 0.53a

[1] Means within a column followed by the same letters are not significantly different (LSD test, $P < 0.05$).

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Table 4 Fumigant toxicity of *Citrus limon* and *Foeniculum vulgare* essential oils on three developmental stages of *Tetranychus turkestani* at 24 h after treatment**.**

Stages	*C. limon*			*F. vulgare*		
	LC_{50} (95% CL)[1] (µl l^{-1} air)	Slope ± SE	χ^2 (df)	LC_{50} (95% CL)[1] (µl l^{-1} air)	Slope ± SE	χ^2 (df)
Egg	11.60	0.05 ± 0.17	6.9	16.08	0.17 ± 1.49	8.2
	(10.36 - 13.14)		(3)	(13.63-20.12)		(3)
2nd instar nymph	7.98	0.22 ± 18.20	14.4	9.86	0.17 ± 1.72	9.3
	(7.23 - 8.8)		(3)	(8.73-11.21)		(3)
Adult	11.52	0.17 ± 1.91	7.2	14.06	0.18 ± 1.95	9.6
	(10.3 - 22.9)		(3)	(12.47-16.27)		(3)

[1] CL: Confidence limits. LC_{50} values are considered significantly different when 95% CL fail to overlap.

Table 5 Fumigant toxicity of *Citrus limon* and *Foeniculm vulgare* essential oils to three developmental stages of *Orius albidipennis* at 24 h after treatment.

Stages	*C. limon*			*F. vulgare*		
	LC_{50} (95% CL)[1] (µl l^{-1} air)	Slope ± SE	χ^2 (df)	LC_{50} (95% CL)[1] (µl l^{-1} air)	Slope ± SE	χ^2 (df)
Egg	29.63	0.18 ± 0.05	4.49	42.41	0.24 ± 0.04	12.43
	(21.78 - 50.41)		(3)	(31.66 - 67.93)		(3)
2nd instar nymph	17.21	0.17 ± 0.05	14.4	34.19	0.19 ± 0.04	34.19
	(14.15 - 22.85)		(3)	(15.25 - 56.21)		(3)
Adult	21.55	0.18 ± 0.07	7.2	35.91	0.21 ± 0.03	9.60
	(17.56 - 29.13)		(3)	(27.41 - 54.91)		(3)

[1] CL: Confidence limits. LC_{50} values are considered significantly different when 95% CL fail to overlap.

Discussion

The essential oils of fennel, lemon and most other plants are environmentally non-persistent pesticides, as they readily volatilize from plants and other surfaces. Some essential oils are nontoxic to non-target organisms and can be used in IPM (Miresmailii *et al.*, 2006). They have a broad spectrum of bioactivity that work through several modes of action and can be applied to plants or stored products in the same way as other conventional insecticides. Many essential oils are known to exhibit ovicidal, repellent and insecticidal activities against various insect and mite species (Desmarchelier, 1994; Isman, 2000).

The current study showed that *F. vulgare* and *C. limon* essential oils have high contact toxicity against *T. turkestani* while having no phytotoxicity effect on the greenhouse cucumber as its host plant. Thus, essential oils and their components can be effectively used to dispel both parasitic and free-living ticks as well as mites (El-Zemity *et al.*, 2006). Also, these essential oils had low contact toxicity against *O. albidipennis*.

This study revealed that high concentrations (800 and 2000 ppm) causegreater mortality to *T. turkestani* stages. The results were similar to those of Yang *et al.* (2010), who showed that mortality of *Bemisia tabaci* Gennadius adults increased as concentrations of *Corymbia citriodora* Hook, *Thymus vulgaris* L. and *Pogostemon cablin* Blanco essential oils were increased.

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Results of the current study showed that the contact toxicity of lemon essential oil was greater than that of fennel essential oil, a difference that can be associated with components of the plant or the susceptibility of the mentioned species. The essential oils of *F. vulgare* and *C. limon* had the highest effects on 2nd instar nymphs and the lowest effect on the eggs of *T. turkestani*. The low toxicity of the essential oils on the mite eggs may be due to different metabolic and physiological characteristics. Yang *et al.* (2010) stated that non-volatile ingredients might be responsible for the low insecticidal activity of the essential oils of *Thymus vulgaris* L., *Pogostemon cablin* Blanco and *Corymbia citriodora* Hook. on sweetpotato whitefly eggs in comparison with the mite nymphs or adults. In bioassay experiments, the toxicity of insecticides could be affected by body size, mobility, or physiological characteristics, e.g. the enzyme activity, of insects (Busevin, 1971). Results of the current study indicated that different concentrations of lemon and fennel essential oils caused mortality in all developmental stages of *T. turkestani*.

The findings of fumigant toxicity tests indicated that lemon and fennel essential oils had high toxicity against *T. turkestani* eggs, 2nd instar nymphs and adults. Lee *et al.* (2006) demonstrated that casethe monoterpene (_)-carvone is the main active component in fennel essential oil that is highly toxic to mites. Additionally, insecticidal activity of major constitutes of lemon essential oil, such as citral (Jeon *et al*., 2009), caryophyllene oxide and neral (Cheng *et al*., 2009), limonene (Tripathi *et al.*, 2003) were previously reported. Digilio *et al.* (2008) reported that in the system pepper/*Myzus persicae* Sulzer, fennel essential oil showed remarkable insecticidal activity with no side effects in terms of phytotoxicity, even at the highest dose. Similar observations were made in the fumigant toxicity of fennel essential oil against *Callosobruchus maculates* (F) adults (Gusmao *et al.*, 2013) and *Trialeurodes vaporariorum* Westwood (Aroiee *et al.*, 2005).

The contact and fumigant toxicity of essential oils was lower against various life stages of *O. albidipennis* than against its prey. The fumigant toxicity of 13 selected essential oils and dichlorvos against adult *Orius strigicollis* Poppius was investigated using the vapor phase toxicity bioassay during a 24-h exposure. Results showed that the adult bug was less susceptible to some oils than the adult of *Thrips palmi* Karny (Chang-Geun *et al.,* 2006).

The results also showed that the fumigant toxicity of lemon essential oil was higher than that of fennel essential oil against the developmental stages of *T. turkestani*. These results are similar to those of Choi *et al.* (2003), who revealed the high fumigant toxicity of lemon oil against *T. voporariorum* eggs, nymphs and adults.

Moreover, our findings showed that the 2nd instar nymph of *T. turkestani* and the 5thinstar nymph of *O. albidipennis* were the most susceptible life stages to both tested essential oils. However, the egg stage of the mite and predator was the most resistant compared with the adult stage.

In conclusion and based on the results obtained from the current research, it can be stated that lemon and fennel essential oils possess great potential for use against *T. turkestani* in greenhouses. The essential oils had relatively toxic effect to various life stages of *O. albidipennis*. Therefore, it is suggested that if the predatory bug is used as a biocontrol agent of *T. tuerestani*, its release time should be properly selected to minimize the side effect by residual toxicity of the essential oil. Further research is required on reducing quality impacts and phytotoxicity of crops treated with the oils and improving the insecticidal potency and stability for practical use of these fumigant oils.

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سمیت تماسی و تدخینی اسانس‌های گیاهان رازیانه و لیمو روی کنه تارتن *Tetranychus turkestani* و شکارگر آن *Orius albidipennis*

نیلوفر فرجی[1]، علی اصغر سراج[1*]، فاطمه یاراحمدی[2] و علی رجب‌پور[2]

۱- گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه شهید چمران، اهواز، ایران.
۲- گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه کشاورزی و منابع طبیعی رامین خوزستان، اهواز، ایران.
* پست الکترونیکی نویسنده مسئول مکاتبه: seraja@gmail.com
دریافت: ۲۴ مرداد ۱۳۹۴؛ پذیرش: ۳۰ دی ۱۳۹۴

چکیده: کنه تارتن ترکستانی *Tetranychus turkestani* یکی از مهم‌ترین آفات گیاهان گلخانه‌ای در استان‌های جنوبی ایران می‌باشد. مزایای زیاد استفاده از اسانس‌های گیاهی نسبت به آفت‌کش‌های شیمیایی، آنها را برای برنامه‌های مدیریت تلفیقی آفات مناسب نموده است. سمیت تماسی و تدخینی اسانس گیاهان رازیانه *Foeniculum vulgare* و لیمو *Citrus limon* برای این کنه و شکارگر آن *Orius albidipennis* در شرایط آزمایشگاهی مورد بررسی قرار گرفت. آزمایش‌های سمیت تماسی با ۶ غلظت (۰، ۵۰، ۱۰۰، ۳۰۰، ۸۰۰ و ۲۰۰۰ پی‌پی‌ام) از هر اسانس روی مراحل نابالغ و بالغ آفت مذکور انجام گرفت و میزان مرگ‌ومیرها ۷۲ ساعت بعد از در معرض قرار گرفتن آفت، ثبت شد. در آزمایش‌های سمیت تدخینی، مقادیر LC_{50} اسانس‌های مورد آزمایش برای مراحل مختلف رشدی *T. turkestani* و *O. albidipennis* تعیین شد. هر دو اسانس در غلظت ۸۰۰ و ۲۰۰۰ پی‌پی‌ام سمیت بالایی روی تخم، دومین سن پورگی و بالغین *T. turkestani* داشتند. این درحالی بود که این غلظت‌ها موجب مرگ‌ومیر پایینی روی *O. albidipennis* شدند. گیاه‌سوزی خاصی توسط این اسانس‌ها مشاهده نشد. مرگ‌ومیر *T. turkestani* و *O. albidipennis* با افزایش غلظت اسانس افزایش می‌یافت. هم‌چنین در کاربرد تماسی، دومین سن پورگی *T. turkestani* این اسانس‌ها نسبت به سایر مراحل رشدی حساس‌تر بودند. در زیست‌سنجی‌های سمیت تدخینی، مقادیر LC_{50} اسانس‌های به‌دست آمده از برای مراحل رشدی تخم، دومین سن پورگی و بالغین برای رازیانه به‌ترتیب ۱۶/۰۸، ۷/۹۸ و ۱۴/۰۶ و برای لیمو به‌ترتیب ۱۱/۶، ۹/۸۶ و ۱۱/۵۲ میکرولیتر/لیتر هوا بود. بیش‌ترین سمیت تدخینی برای دومین سن پورگی این آفت مشاهده شد. سمیت تدخینی این اسانس‌های گیاهی روی *O. albidipennis* کمتر از *T. turkestani* بود. این نتایج نشان می‌دهد که اسانس‌های گیاهی موردنظر پتانسیل خوبی برای کاربرد در برنامه‌های مدیریت تلفیقی کنه تارتن ترکستانی در محصولات گلخانه‌ای به‌ویژه خیار دارند.

واژگان کلیدی: اسانس‌های گیاهی، سمیت تماسی، سمیت تدخینی، گیاه‌سوزی

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