

Fumigant Toxicity of Tarragon (*Artemisia dracunculus* L.) and Dill (*Anethum graveolens* L.) Essential Oils on Different Life Stages of *Trialeurodes vaporariorum* (Westwood)

M. MOUSAVI^{1*}, N. MAROUFPOOR² and O. VALIZADEGAN¹

¹Department of Plant Protection, Faculty of Agriculture, Urmia University, Urmia, Iran

²Young Researchers and Elite Club, Boukan Branch, Islamic Azad University, Boukan, Iran

(Received: 12 July 2017; accepted: 11 August 2017)

Trialeurodes vaporariorum (Westwood) is a polyphagous species. This pest is now well-established in the greenhouse ecosystem and is an economically important pest of horticultural and ornamental crops. The fumigants toxicity of tarragon (*Artemisia dracunculus* L.) and dill (*Anethum graveolens* L.) essential oils on the life stages of *Trialeurodes vaporariorum* were investigated under laboratory conditions. Plants essence samples were obtained from the aerial parts of the plant by using Clevenger device. In this study, six concentrations (5 concentrations and one control) were used to evaluate LC₅₀ level and five time periods were used for LT₅₀. The LC₅₀ values for *Artemisia dracunculus* and *Anethum graveolens* at 24 h after treatment of the eggs, nymphs and adults were 1.18, 0.45 and 0.69 $\mu\text{l l}^{-1}$ air and 12.99, 5.67 and 8.03 $\mu\text{l l}^{-1}$ air, respectively. Also, the LT₅₀ value of tarragon essential oil on the eggs, nymphs and adults were 15.02, 5.12 and 9.05 hours and for dill were 18.66, 5.51 and 10.14 hours, respectively.

Keywords: Dill, essential oil, fumigant toxicity, greenhouse whitefly, tarragon.

According to the temperature and humidity conditions of greenhouses, many pests are active in there and greenhouse whitefly is one of these most important pests. This polyphagous pest feeds on plant sap and excreting honeydew that prepares the conditions for the growth of sooty mold and transmit more than 100 plant viruses (Rezaei et al., 2015). Unfortunately, in order to reduce the damage caused by this pest in greenhouses, typically, chemical pesticides are used (van Lenteren, 2000). These compounds have adverse consequences such as ozone depletion, environmental pollution, toxicity to non-target organisms, development of resistance and pesticide residue (Ogendo et al., 2003). These problems have led researchers to seek alternative and environment-friendly methods to control the pests (Tapondjou et al., 2005). Among these, the use of essential oils can be mentioned. The active compounds derived from plant extracts and essential oils may have fumigant effects on pests (Regnault-Roger et al., 2012).

These essential oils are extracted from aromatic plants because of their intense odor, less toxic to mammals, no significant adverse impact on the environment and they're pop-

* Corresponding author; e-mail: mousavimahdieh@yahoo.com

ular acceptance, are considered very useful compounds for pest control (Isman, 2000; Trumble, 2002). At present, over 3000 essential oils have been identified, and 300 of the essences and their compounds have commercial importance in the pharmaceutical, agronomic, food, health, cosmetics and perfume industry (Bakkali et al., 2008).

Plant essential oils may have repellent (Ogendo et al., 2008), insecticidal (Papachristos and Stamopoulos, 2002), antifungal (Kotan et al., 2008), antibacterial (Mata-syoh et al., 2007), antiviral (Schuhmacher et al., 2003), oviposition and feeding deterrence and growth inhibition effects (Papachristos and Stamopoulos, 2002; García et al., 2007). So far, many studies have been performed on the insecticidal properties of plant essential oils, for example, Aroiee et al. (2005) demonstrated the cytotoxic effect of rosemary (*Rosmarinus officinalis* L.), fennel (*Foeniculum vulgare* M.) and caraway (*Carum carvi* L.) essential oils on greenhouse whitefly.

Delkhoon et al. (2013) studied the insecticide properties of essential oils of lemon peel (*Citrus aurantifolia* Hook) on greenhouse whitefly and concluded that this essence has a good controlling effect on the pest. In another experiment, Nouri Ganbalani et al. (2010) examined the effects of some plant essences including (*Artemisia dracunculus*) on egg laying and feeding behavior of Colorado potato beetle (*Leptinotarsa decemlineata* Say.) that exhibited tarragon essential oil had repellency against adult females.

Rafiei Karahroodi et al. (2009) studied repellency and fumigant toxicity of 18 species of plant essential oils such as (*Anethum graveolens*) on Hindi moth (*Plodia interpunctella* Hübner) and concluded that the essential oil of dill has significant fumigant toxicity and very high repellency on this pest.

In this study, the insecticidal effects of plant essences of tarragon and dill were tested on greenhouse whitefly in order to effectively control the pest as well as reducing the amount of chemical insecticide being used.

Materials and Methods

Insects rearing

Greenhouse whiteflies were grown in the greenhouse and on tomato plants at 27 ± 2 °C and $65 \pm 5\%$ relative humidity (RH) and a photoperiod of 16:8 L: D. To synchronize the developmental stages, 20-30 adult insects were transferred into small plastic cages (8 cm diameter \times 9 cm height) according to the method by Muñiz and Nombela (2001). The adults were transferred to cages for spawning. After 48 h insects were removed from the plants by the aspirator. The infested plants were held in the same condition.

Extraction of essential oils

Dried parts of tarragon plants except wooden stem and dill seeds were grounded to powder. In each essential oil extraction cycle, 50g of herbal powder was extracted with 600 ml of distilled water using a Clevenger apparatus and hydro-distillation for 3 hours. Extracted oil was dried with anhydrous sodium sulfate and stored in sealed vials at 4 °C

(Negahban et al., 2006). Compounds forming the oil were determined by gas chromatography coupled with mass spectrometry.

Gas chromatography–mass spectrometry analysis

The constituents of two essential oils were analyzed by gas chromatography–mass spectrometry (GC–MS) using a Shimadzu-9A gas chromatograph equipped with a flame ionization detector (FID) and with PH-5 capillary column (30 m × 0.1 mm; 0.25 µm film thickness). The oven temperature was held at 60 °C for 3 min, programmed at 20 °C/min to 240 °C and then held at this temperature for 8.5 min. The carrier gas was helium in a flow rate of 1 ml/min. Mass spectra was taken at 70 eV. The injector temperature was 280 °C. Identification of the constituents of the oils was made by comparison of their mass spectra and retention indices with those given in the literature and those authentic samples (Adams, 1997).

Determining the 50% (LC₅₀) lethal concentration for the eggs and nymphs

The method of application to determine the toxicity of essential oils on the eggs and nymphs was based on Kéita et al. (2001). In this method, without being separated from the plant, leaves containing eggs and nymphs of the same age were placed in dishes which were 305 ml with a groove at its edge and the edges were sealed with wax. Various (0.33, 0.66, 0.98, 1.31 and 1.64 µl l⁻¹ air for tarragon and 3.28, 6.56, 9.84, 13.11 and 16.39 µl l⁻¹ air for dill) concentrations of essential oils were applied to filter papers and each treatment was replicated three times and each experiment contained 20 insects of the same age. Plates were then sealed with parafilm to prevent any loss of essential oils. An estimate of toxicity of the test oils to the eggs was based on the color change of the eggs. *Trialeurodes vaporariorum* freshly laid eggs are yellowish but turn black after 1 or 2 days. After 24 h exposure to essential oil, counting of the eggs was done when they were discolored and those eggs which remained yellow were considered dead (Fahim et al., 2012). Nymphs were also exposed to the essential oils for 24 h and afterward the dead and live nymphs were counted. Nymphs that were dry, discolored or removed easily from leaves were considered dead (Gökçe and Er, 2005). The control treatment consisted of a similar setup but without essential oils.

Determining the 50% (LC₅₀) lethal concentration for adults

Various concentrations of each essential oil were applied to filter papers based on Kéita et al. (2001) and each treatment was repeated three times. After drying, each treated filter paper was placed into dishes of 305 ml. Each treatment contained 20 adults along with a nutritional material (tomato leaf). Petioles of tomato leaf were wrapped with water soaked cotton. Also, to prevent a direct contact between the insects and the tested oils, a mesh was implanted within the cap and the container. The container was sealed with parafilm. Evaluation of mortality was made 24 h after exposure. Insects that did not show any

movement with nearing the brush were considered as dead (Choi et al., 2003). Distilled water was used as control treatment.

Determining the 50% (LT₅₀) lethal time

Due to tests of the lethal time of essential oils, the calculated LC₅₀ value for both of the essential oils was evaluated on different stages of greenhouse whitefly life in 5 times including 2, 7, 12, 18 and 24 hour to obtain the desired LT₅₀. Other tests were done like determination of the lethal concentration of LC₅₀.

Statistical analysis

To determine the LC₅₀ after 24 hours of essential oil exposure, percentage mortality was corrected by Abbott's formula (Abbott, 1925) and to determine the LT₅₀, an essential oil concentration at different times (2, 7, 12, 18 and 24 h) was used. Data were analyzed by employing ANOVA and means were compared by Tukey's test ($p < 0.01$) using SPSS software (Ver. 20). The dendrogram similarity scales that are produced by the SPSS (V. 20) software range from zero (most similarity) to 25 (least similarity). Hierarchical cluster analysis and component analysis were carried out according to Ward (1963). Cluster validity index called Silhouette index is applied to validate the result by MATLAB Software (Rousseeuw, 1987).

Results

Lethal concentration (LC₅₀) values of tarragon and dill essential oils are shown in Table 1. The lowest LC₅₀ values were recorded against the nymphs, for tarragon essential oil ($0.45 \mu\text{l l}^{-1}$ air) followed by dill ($5.67 \mu\text{l l}^{-1}$ air). Therefore, it can be concluded that the nymphs of *T. vaporariorum* are more susceptible to the essential oils than adult and egg life stages. Considering confidence limits (CL) overlapping, LC₅₀ values were significantly different for three developmental stages for two essential oils. In fumigant application essential oil derived from *Ar. dracunculus* was more toxic than *An. graveolens* essential oil. ANOVA indicated that F values for both essential oils after 24 h exposure were significantly different for three developmental stages of greenhouse whitefly, as respects F values for *Ar. dracunculus* was 20.560 in eggs, 58.127 in nymphs and 34.114 in adults, while for *An. graveolens* was 60.914 in eggs, 47.2 in nymphs and 22.12 in adults (df: 4, 10; $p < 0.01$). A comparison of the mean effect size of the exposure time of both essential oils on three developmental stages of whitefly is shown in Tables 2 and 3. Results showed that mortality percentage of three developmental stages of *T. vaporariorum* increased as concentrations of the two essential oils increased. The essential oil extracted from *Ar. dracunculus* showed high fumigant effect on nymphs of whitefly. The results of the experiments in the lethal time (LT₅₀) illustrated that tarragon essential oil has a significant effect on *T. vaporariorum*. An estimation of the LT₅₀ value was done 24 h after exposure

Table 1
Fumigant toxicity of *Artemisia dracunculus* and *Anethum graveolens* essential oils on three developmental stages of *Trialeurodes vaporariorum* 24 h after treatment

Stages	<i>Ar. dracunculus</i>			<i>An. graveolens</i>		
	LC ₅₀ (95% CL) ($\mu\text{l l}^{-1}$ air)	Slope \pm SE	χ^2 (df)	LC ₅₀ (95% CL) ($\mu\text{l l}^{-1}$ air)	Slope \pm SE	χ^2 (df)
Egg	1.18 (1.07–1.32)	3.77 \pm 0.46	6.66 (3)	12.99 (11.75–14.69)	3.94 \pm 0.51	5.86 (3)
Nymph	0.45 (0.39–0.51)	3.74 \pm 0.42	7.16 (3)	5.67 (4.86–6.42)	3.18 \pm 0.36	10.91 (3)
Adult	0.69 (0.60–0.77)	3.46 \pm 0.37	9.75 (3)	8.03 (7.23–8.85)	3.94 \pm 0.40	4.04 (3)

Table 2
Fumigant mortality percentages of *Artemisia dracunculus* essential oil against three developmental stages of *Trialeurodes vaporariorum*

Concentration ($\mu\text{l l}^{-1}$ air)	Mortality \pm SE (%)		
	Egg	Nymph	Adult
0.33	8.81 \pm 4.12c	28.67 \pm 3.08c	18.05 \pm 2.85c
0.66	23.74 \pm 3.37bc	45.0 \pm 3.33bc	35.17 \pm 2.72bc
0.98	37.12 \pm 3.66ab	59.24 \pm 4.08b	47.91 \pm 3.35b
1.31	48.88 \pm 3.48ab	81.20 \pm 4.12a	59.05 \pm 2.84ab
1.64	60.96 \pm 6.95a	89.43 \pm 0.001a	77.91 \pm 6.43a

Different letters correspond to significant differences ($P < 0.05$)

Table 3
Fumigant mortality percentages of *Anethum graveolens* essential oil against three developmental stages of *Trialeurodes vaporariorum*

Concentration ($\mu\text{l l}^{-1}$ air)	Mortality \pm SE (%)		
	Egg	Nymph	Adult
3.28	8.81 \pm 4.12d	33.08 \pm 3.08d	15.19 \pm 7.68c
6.56	16.60 \pm 1.84cd	44.01 \pm 4.21cd	33.00 \pm 3.66bc
9.84	30.95 \pm 2.84bc	57.10 \pm 4.72bc	50/85 \pm 3.40ab
13.11	45.96 \pm 0.96ab	70.11 \pm 1.45ab	63/93 \pm 4.27ab
16.39	56.84 \pm 1.81a	89.43 \pm 0.001a	77.52 \pm 5.95

Different letters correspond to significant differences ($P < 0.05$)

of the greenhouse whitefly, the lowest LT₅₀ values were recorded against the nymphs, that LT₅₀ values for tarragon and dill essential oil were 5.12 and 5.51, respectively. In all the three developmental stages, LT₅₀ values were not significantly different between the two essential oil treatments (Table 4).

According to the analysis of essential oil by gas chromatography (GC/MS), tarragon essential oil is composed of 19 compounds, the most abundant ones are: estragole (71.53%), *cis-beta* ocimene (9.41%) and *trans-beta* ocimene (6.11%). The dill essen-

tial oil is composed of 13 compounds, the most important ones are: carvone (52.2%), limonene (17.1%), γ -terpinene (8.5%) and trans-dihydrocarvone (8.4%) (Table 5).

Component analysis and hierarchical cluster analysis

To investigate the relationship between essential oils composition of the previously reported samples and our studied oils, hierarchical cluster analysis (HCA) and component analysis were carried out based on similar components of reported essential oil in the

Table 4
LT₅₀ of *Artemisia dracunculus* and *Anethum graveolens* essential oils in LC₅₀ concentration on three developmental stages of *Trialeurodes vaporariorum* 24 h after treatment

Stages	<i>Ar. dracunculus</i>			<i>An. graveolens</i>		
	LT ₅₀ (95% CL) (hours)	Slope \pm SE (hours)	χ^2 (df)	LT ₅₀ (95% CL)	Slope \pm SE	χ^2 (df)
Egg	15.02 (12.93–17.79)	2.51 \pm 0.32 (3)	3.32 (16.37–22.11)	18.66 (3)	3.10 \pm 0.45	0.43
Nymph	5.12 (1.07–9.56)	2.44 \pm 0.25 (3)	15.17 (1.44–10.01)	5.51 (3)	2.41 \pm 0.25	13.96
Adult	9.05 (7.63–10.59)	2.37 \pm 0.26 (3)	7.69 (8.59–11.86)	10.14 (3)	2.37 \pm 0.27	6.73

Table 5
Chemical composition of tarragon (*Artemisia dracunculus*) and dill (*Anethum graveolens*) extracts by gas chromatography mass spectrometry (GC/MS)

<i>Ar. dracunculus</i>	% in essence	<i>An. graveolens</i>	% in essence
methyl eugenol	1.79	cis dihydrocarvone	1.8
bornyl acetate	0.28	dill ether	0.8
allo ocimene	0.51	P-cymene	6.8
spathulenol	0.21	myrcene	0.3
β -pinene	0.31	α -phellandrene	7.2
limonene	4.93	γ -terpinen	8.5
α -terpinolene	0.18	limonene	17.1
comphene	0.09	sabinene	0.1
α -pinene	1.61	β -pinene	0.2
cis- beta-ocimene	9.41	trans dihydrocarvone	8.4
sabinene	0.16	carvone	52.2
eugenol	0.21	dill apiol	2.7
germacrene-D	0.12	α -pinene	0.1
phytol	0.32		
myrcene	0.29		
trans-beta-ocimene	6.11		
estragole	71.53		
bicyclogermacrene	0.22		
P-anisaldehyde	0.11		

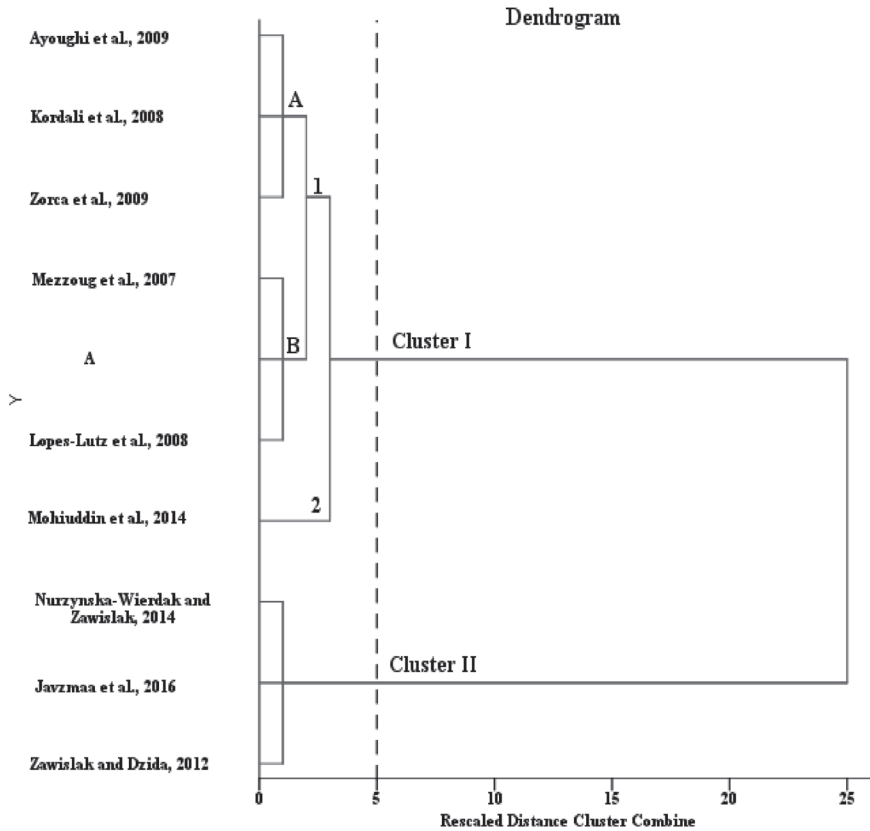


Fig. 1. Dendrogram generated from cluster analysis of *Artemisia dracunculus* essential oils based on the chemical compounds of the investigated sample (A) and those reported in the earlier articles. Two main clusters were marked by the dotted line. Cluster I is divided into 2 subclusters; also subcluster I.1 has divided into subclusters, I.1.A and I.1.B.

articles. The dendrogram for the HCA results using Ward’s clustering algorithm for *Ar. dracunculus* is shown in (Fig. 1). The Silhouette index showed that samples of *Ar. dracunculus* could be clustered into two well-defined groups (Table 6). Cluster I is divided into two sub-clusters (sub-cluster I 1-2). Sub-cluster I.1 is further divided into sub-cluster I.1A and I.1B. Sub-cluster I.1A of three samples (Kordali et al., 2008; Ayoughi et al., 2009; Zorca et al., 2009) is characterized by (Z)- β -ocimene and (E)- β -ocimene as the major compounds. Our studied essential oils with two other samples (Mezzoug et al., 2007; Lopes-Lutz et al., 2008) formed the Sub-cluster I.1B. In For sub-cluster I.1B, (E)- β -ocimene was the main compound. Sub-cluster I-2 represented by one sample had (Z)- β -ocimene as the major constituent (Mohiuddin et al., 2014). Cluster II included three samples, those with high sabinene levels (Zawislak and Dzida, 2012; Nurzyńska-Wierdak and Zawislak, 2014; Javzmaa et al., 2016).

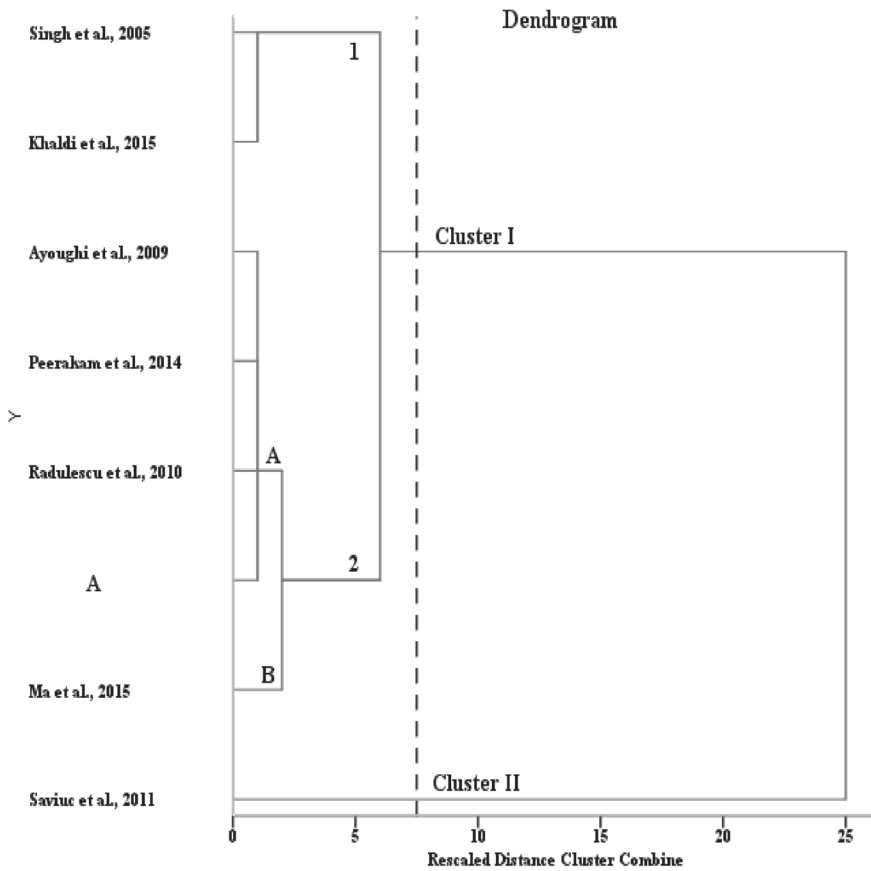


Fig. 2. Dendrogram obtained from cluster analysis of *Anethum graveolens* essential oils based on the chemical compounds of the investigated sample (A) and those reported in the earlier articles. Two main clusters were marked by the dotted line. Cluster I is divided into 2 subclusters; also Subcluster I.2 has divided into subclusters, I.2.A and I.2.B.

Table 6

The result of average Silhouette index for the number of possible main clusters in *Artemisia dracunculus*

Cluster	2	3	4
Index	0.9224	0.5404	0.7871

Table 7

The result of average Silhouette index for the number of possible main clusters in *Anethum graveolens*

Cluster	2	3	4
Index	0.9224	0.8674	0.8924

The dendrogram of *An. graveolens* essential oils is shown in (Fig. 2). The dendrogram based on the Silhouette index was divided into two groups (Table 7). The first group (Cluster I), represented by two sub-cluster (sub-cluster I 1-2), that sub-cluster I-1 included were two samples with high E-dihydrocarvone (Singh et al., 2005; Khaldi et al., 2015). Sub-cluster I-2 was divided into two groups (Sub-cluster I.2 A-B). That studied with three samples formed the sub-cluster I.2-A that limonene and trans-dihydrocarvone were the main components (Ayoughi et al., 2009; Radulescu et al., 2010; Peerakam et al., 2014). In sub-cluster I.2-B with one sample carvone and limonene (Ma et al., 2015). Cluster II formed the individual group separating from the other samples that characterized by limonene (Saviuc et al., 2011).

Discussion

Due to increased pest resistance to chemical pesticides and reports on these pesticide residues in products and environmental pollution, plant essential oils provide a low risk option to control greenhouse whitefly (Quarles, 2005). Hence, in this study the insecticidal properties of essential oils of (*Ar. dracuncululus*) and (*An. graveolens*) on different life stages of greenhouse whitefly were studied. The results of this study show that the mentioned essences have a significant lethal effect on *T. vaporariorum* and it was found that mortality depended on exposure time and concentration of essential oil.

The fumigation activity was assessed through a method described by Choi et al. (2003), Aslan et al. (2004), and Fahim et al. (2012). Choi et al. (2003) studied the fumigant effect of 53 plant extracts against different life stages (egg, nymph and adult) of greenhouse whitefly, the results of the experiments showed that oregano (*Origanum vulgare*), Eucalyptus (*Eucalyptus globulus*), clove (*Syzygium aromaticum*), cumin (*Cuminum cyminum*) and peppermint (*Mentha spicata*) essential oils were the most effective in controlling adults, nymphs and eggs of this pest, respectively. In another experiment, Aroiee et al. (2005) demonstrated the insecticidal activity of essential oils of thyme (*Thymus vulgaris* L.) and spearmint (*Mentha piperita* L.) on greenhouse whitefly.

Choi et al. (2003) and Aroiee et al. (2005) reported similar evidence on insecticidal activity of plant essential oils on greenhouse whitefly. Also, Fahim et al. (2012) evaluated the sensitivity of egg, nymph and adult of greenhouse whitefly to two plant essential oils of peppermint and cumin in laboratory conditions. The essential oil derived from peppermint was more toxic than cumin essential oil in fumigant application and also, the first instar nymphs were more susceptible than adults and egg life stages to the essential oils. The findings of this study are in correspondence with the results of other researchers about the effect of essential oils on greenhouse whitefly populations.

Delkhoon et al. (2013) studied insecticidal properties of essential oil of lemon peel (*Citrus aurantifolia*) on the egg and the first nymphal stage and adults egg-laying stages of greenhouse whitefly under laboratory conditions, and because of having an acceptable controlling effect, introduced the essence as an appropriate biological insecticide to control this pest. Therefore, this research finding corresponds to our results on pest control with the essential oils.

In addition to the insecticidal activity of some of the essential oils on greenhouse whitefly, their repellent effects on the pest have also been demonstrated (Santiago et al., 2009). Some examples have illustrated the potential of essential oils as the insecticide for another species of whiteflies. For example, fumigant activity of essential oils of 3 plant species including *Satureja hortensis* L., *Ocimum basilicum* L. and *Thymus vulgaris* L. on adults and nymphs of *Bemisia tabaci* (Hom: Aleyrodidae) have been reported (Aslan et al., 2004). Also controlling effect of essential oils extracted from aromatic plants such as *Satureja hortensis* L., *Origanum vulgare* L. and *Nepeta racemosa* L. on *B. tabaci* are marked (Çalmaşur et al., 2006). Furthermore, the significant reduction of hatching eggs, nymphs and pupae survival and oviposition of *B. tabaci* because of the effect of essential oils of *Thymus vulgaris* L., *Pogostemon cablin* B. and *Corymbia citriodora* H. (Yang et al., 2010) confirmed.

The results of the present study are in agreement with the previous study based on the controlling effect of plant essential oils on the family Aleyrodidae). The essential oils of tarragon and dill had the highest effects on the nymphal stage and the lowest effect on the eggs. These results are in accordance with findings of Yang et al. (2010) and Choi et al. (2003). These researchers reported that in their experiments on greenhouse whitefly and *Bemisia tabaci*, the sensitivity of the adults is lower compared to nymphal stages but higher compared to eggs and pupae. The low toxicity of the essential oils on the eggs may be due to the impenetrable chorionic layer of the egg. Plant essential oils of tarragon and dill and also their mixture have been used frequently in tests to control various pests. For example, Manzoomi et al. (2010), investigated fumigant toxicity of essences of 3 plants such as tarragon on adult cowpea beetle (*Callosobruchus maculatus*) and found that they have potent insecticidal activity on this storage pest.

Saadali et al. (2001) demonstrated, insecticidal properties of alkaloids and coumarin extracted from the aerial parts of tarragon on two storage pest species *Sitophilus oryzae* and *Rhyzopertha dominica*. The results of this study are compatible with the results of Manzoomi et al. (2010) and Saadali et al. (2001) based on the controlling effect of tarragon essential oil and its components on different pests.

According to recent findings of various studies on the insecticidal activity of plant essential oils of different *Artemisia* species against storage pests have been conducted. For instance, toxicities and insecticidal activity of *A. annua*, *A. aucheri*, *A. sieberi*, *A. scoparia*, *A. judaica*, *A. herba-alba*, *A. vulgaris* and *A. absinthium* on storage pests have been reported (Aggarwal et al., 2001; Shakarami et al., 2004; Negahban et al., 2006, 2007; Derwich et al., 2009; Abd-Elhady, 2012; Pugazhvendan et al., 2012; Sharifian et al., 2012). The results of the present study have corresponded to the results of studies based on the lethal effect of the essential oil of *Artemisia* genus on different pests.

(Ariana et al., 2002) reported the acaricidal effects of dill essential oil against varroa mite (*Varroa destructor*) in laboratory and concluded that the essences on bees infected with these mites after a week, with a minimum loss in the honey bee, because of a loss in varroa mites.

Also, Mikhael (2011) reported the lethal effect of dill plant essential oil on *Ephesia kuehniella* and *Tribolium castaneum* larvae. The results of this study correspond to the results of Aroiee et al. (2005) on controlling the target pests by dill plant essences. Trip-

athi et al. (2001) have reported that the essence of another species of the dill plant genus named *Anethum sowa* in 10 µl/ml volume concentrations inhibits oviposition in cowpea beetle. The information obtained from this study is similar to that of other results about pest controlling effect of essential oils of genus *Anethum*.

In conclusion and based on the results obtained from this study, it can be stated that tarragon and dill essential oils possess potential to be extended as possible natural fumigants for the control of greenhouse whitefly in comparison of synthetic fumigants (insecticides) because of safety for the environment and human health and the use of essential oils is recommended in integrated pest management, particularly for greenhouse pests.

Literature

- Abbott, W. (1925): A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* 18, 265–267.
- Abd-Elhady, H. (2012): Insecticidal activity and chemical composition of essential oil from *Artemisia judaica* L. against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *J. Plant Protection Research* 52, 347–352.
- Adams, R. (1997): Identification of essential oil components by gas chromatography/mass spectroscopy. *J. American Society for Mass Spectrometry* 6, 671–672.
- Aggarwal, K. K., Tripathi, A. K., Prajapati, V. and Kumar, S. (2001): Toxicity of 1, 8-cineole towards three species of stored product coleopterans. *International J. Tropical Insect Science* 21, 155–160.
- Ariana, A., Ebadi, R. and Tahmasebi, G. (2002): Laboratory evaluation of some plant essences to control Varroa destructor (Acari: Varroidae). *Experimental and Applied Acarology* 27, 319–327.
- Aroiee, H., Mosapoor, S. and Hosainy, M. (2005): Effect of essential oils of fennel, caraway and rosemary on greenhouse whitefly (*Trialeurodes vaporariorum*). *KMITL Science Journal* 5, 506–510.
- Aslan, I., Özbek, H., Çalmaşur, Ö. and Şahin, F. (2004): Toxicity of essential oil vapours to two greenhouse pests, *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. *Industrial Crops and Products* 19, 167–173.
- Ayoughi, F., Brzegar, M., Sahari, M. A. and Naghdi Badi, H. (2009): Survey Antioxidant activity of dill (*Anethum graveolens*) in soybean oil and compare it with the chemical antioxidants. *Medicine Plants* 8, 71–83.
- Bakkali, F., Averbeck, S., Averbeck, D. and Idaomar, M. (2008): Biological effects of essential oils – a review. *Food and Chemical Toxicology* 46, 446–475.
- Çalmaşur, Ö., Aslan, I. and Şahin, F. (2006): Insecticidal and acaricidal effect of three Lamiaceae plant essential oils against *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. *Industrial Crops and Products* 23, 140–146.
- Choi, W. I., Lee, E. H., Choi, B. R., Park, H. M. and Ahn, Y. J. (2003): Toxicity of plant essential oils to *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). *J. Econ. Entomol.* 96, 1479–1484.
- Delkhoo, S., Fahim, M., Hosseinzadeh, J. and Panahi, O. (2013): Effect of lemon essential oil on the developmental stages of *Trialeurodes vaporariorum* West (Homoptera: Aleyrodidae). *Archives of Phytopathology and Plant Protection* 46, 569–574.
- Derwich, E., Benziane, Z. and Boukir, A. (2009): Chemical compositions and insecticidal activity of essential oils of three plants *Artemisia* sp: *Artemisia herba-alba*, *Artemisia absinthium* and *Artemisia pontica* (Morocco). *Electronic J. Environmental, Agricultural and Food Chemistry* 8, 1202–1211.
- Fahim, M., Safar Alizadeh, M. H. and Safavi, S. A. (2012): Susceptibility testing of eggs, nymphs and adults of greenhouse whitefly towards the herbal essences of Peppermint and Cumin in vitro. *J. Agricultural Science and Sustainable Production* 22, 27–35.
- García, M., Gonzalez-Coloma, A., Donadel, O. J., Ardanaz, C. E., Tonn, C. E. and Sosa, M. E. (2007): Insecticidal effects of *Flourensia oolepis* Blake (Asteraceae) essential oil. *Biochem. Syst. Ecol* 35, 181–187.
- Gökçe, A. and Er, M. K. (2005): Pathogenicity of Paecilomyces spp. to the glasshouse whitefly, *Trialeurodes vaporariorum*, with some observations on the fungal infection process. *Turkish J. Agriculture and Forestry* 29, 331–340.
- Isman, M. B. (2000): Plant essential oils for pest and disease management. *Crop Protection* 19, 603–608.

- Javzmaa, N., Altantsetseg, S., Shatar, S., Enkhjargal, T. and Anu, Z. (2016): Specific characteristics of essential oils of four *Artemisia* species from the Mongolian Trans-Altai Gobi. *Mongolian J. Chemistry* 16, 34–38.
- Kéita, S. M., Vincent, C., Schmit, J. P., Arnason, J. T. and Bélanger, A. (2001): Efficacy of essential oil of *Ocimum basilicum* L. and *O. gratissimum* L. applied as an insecticidal fumigant and powder to control *Callosobruchus maculatus* (Fab.) [Coleoptera: Bruchidae]. *J. Stored Products Research* 37, 339–349.
- Khalidi, A., Meddah, B., Moussaoui, A., Sonnet, P. and Akerny, M. M. (2015): Chemical composition and antifungal activity of essential oil of *Anethum graveolens* L. from South-western Algeria (Bechar). *J. Chemical and Pharmaceutical Research* 7, 615–620.
- Kordali, S., Cakir, A., Ozer, H., Cakmakci, R., Kesdek, M. and Mete, E. (2008): Antifungal, phytotoxic and insecticidal properties of essential oil isolated from Turkish *Origanum acutidens* and its three components, carvacrol, thymol and p-cymene. *Bioresource Technology* 99, 8788–8795.
- Kotan, R., Kordali, S., Cakir, A., Kesdek, M., Kaya, Y. and Kilic, H. (2008): Antimicrobial and insecticidal activities of essential oil isolated from Turkish *Salvia hydrangea* DC. ex Benth. *Biochemical Systematics and Ecology* 36, 360–368.
- Lopes-Lutz, D., Alviano, D. S., Alviano, C. S. and Kolodziejczyk, P. P. (2008): Screening of chemical composition, antimicrobial and antioxidant activities of *Artemisia* essential oils. *Phytochemistry* 69, 1732–1738.
- Ma, B., Ban, X., Huang, B., He, J., Tian, J., Zeng, H., Chen, Y. and Wang, Y. (2015): Interference and mechanism of dill seed essential oil and contribution of carvone and limonene in preventing *Sclerotinia* rot of rapeseed. *PloS one* 10, e0131733.
- Manzooqi, N., Ganbalani, G. N., Dastjerdi, H. R. and Fathi, S. A. A. (2010): Fumigant toxicity of essential oils of *Lavandula officinalis*, *Artemisia dracunculus* and *Heracleum persicum* on the adults of *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Munis Entomology and Zoology* 5, 118–122.
- Matasyoh, L. G., Matasyoh, J. C., Wachira, F. N., Kinyua, M. G., Muigai, A. W. T. and Mukiama, T. K. (2007): Chemical composition and antimicrobial activity of the essential oil of *Ocimum gratissimum* L. growing in Eastern Kenya. *African J. Biotechnology* 6, 760–765.
- Mezzoug, N., Elhadri, A., Dallouh, A., Amkiss, S., Skali, N., Abrini, J., Zhiri, A., Baudoux, D., Diallo, B. and El Jaziri, M. (2007): Investigation of the mutagenic and antimutagenic effects of *Origanum compactum* essential oil and some of its constituents. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis* 629, 100–110.
- Mikhael, A. (2011): Potential of some volatile oils in protecting packages of irradiated wheat flour against *Ephesia kuehniella* and *Tribolium castaneum*. *J. Stored Products Research* 47, 357–364.
- Mohiuddin, D., Ganai, B., Chishti, M., Ahmad, F. and Dar, J. S. (2014): Phytochemical studies on the extract and essential oils of *Artemisia dracunculus* L. (Tarragon). *African J. Plant Science* 8, 72–75.
- Muñiz, M. and Nombela, G. (2001): Differential variation in development of the B- and Q-biotypes of *Bemisia tabaci* (Homoptera: Aleyrodidae) on sweet pepper at constant temperatures. *Environmental Entomology* 30, 720–727.
- Negahban, M., Moharrampour, S. and Sefidkon, F. (2006): Chemical composition and insecticidal activity of *Artemisia scoparia* essential oil against three coleopteran stored-product insects. *J. Asia-Pacific Entomology* 9, 381–388.
- Negahban, M., Moharrampour, S. and Sefidkon, F. (2007): Fumigant toxicity of essential oil from *Artemisia sieberi* Besser against three stored-product insects. *J. Stored Products Research* 43, 123–128.
- Nouri Ganbalani, G., Fathi, S. A. A. and Barmaki, M. (2010): Effects of some plant essential oils on ovipositor and feeding behavior of *Leptinotarsa decemlineata* Say (Col.: Chrysomelidae). *J. Agricultural Science* 3, 1–9.
- Nurzyńska-Wierdak, R. and Zawislak, G. (2014): Herb yield and bioactive compounds of tarragon (*Artemisia dracunculus* L.) as influenced by plant density. *Acta Scientiarum Polonorum. Hortorum Cultus* 13, 207–221.
- Ogendo, J., Belmain, S., Deng, A. and Walker, D. (2003): Comparison of toxic and repellent effects of *Lantana camara* L. with *Tephrosia vogelii* Hook and a synthetic pesticide against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in stored maize grain. *International J. Insect Science* 23, 127–135.
- Ogendo, J., Kostyukovsky, M., Ravid, U., Matasyoh, J., Deng, A., Omolo, E., Kariuki, S. and Shaaya, E. (2008): Bioactivity of *Ocimum gratissimum* L. oil and two of its constituents against five insect pests attacking stored food products. *J. Stored Products Research* 44, 328–334.

- Papachristos, D. and Stamopoulos, D. (2002): Repellent, toxic and reproduction inhibitory effects of essential oil vapours on *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). *J. Stored Products Research* 38, 117–128.
- Peerakam, N., Wattanathorn, J., Punjaisee, S., Buamongkol, S., Sirisa-Ard, P. and Chansakaow, S. (2014): Chemical profiling of essential oil composition and biological evaluation of *Anethum graveolens* L. (seed) grown in Thailand. *J. Natural Sciences Research* 4, 34–41.
- Pugazhvendan, S., Ross, P. R. and Elumalai, K. (2012): Insecticidal and repellent activities of four indigenous medicinal plants against stored grain pest, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Asian Pacific J. Tropical Disease* 2, 16–20.
- Quarles, W. (2005): Neem protects ornamentals in greenhouses and landscapes. *IPM practitioner* 25, 1–14.
- Radulescu, V., Popescu, M. L. and Ilies, D. C. (2010): Chemical composition of the volatile oil from different plant parts of *Anethum graveolens* L. (Umbelliferae) cultivated in Romania. *Farmacia* 58, 594–600.
- Rafiei Karahoodi, Z., Moharrampour, S., Farazmand, H. and Karimzadeh-Esfahani, J. (2009): Effect of eighteen plant essential oils on nutritional indices of larvae *Plodia interpunctella* Hubner (Lep., Pyralidae). *J. Entomological Research* 1, 209–219.
- Regnault-Roger, C., Vincent, C. and Arnason, J. T. (2012): Essential oils in insect control: low-risk products in a high-stakes world. *Annual Rev. Entomol.* 57, 405–424.
- Rezaei, N., Karimi, J., Hosseini, M., Goldani, M. and Campos-Herrera, R. (2015): Pathogenicity of two species of entomopathogenic nematodes against the greenhouse whitefly, *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae), in laboratory and greenhouse experiments. *J. Nematology* 47, 60.
- Rousseeuw, P. J. (1987): Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. *J. Computational and Applied Mathematics* 20, 53–65.
- Saadali, B., Boriky, D., Blaghen, M., Vanhaelen, M. and Talbi, M. (2001): Alkamides from *Artemisia dracunculul*s. *Phytochemistry* 58, 1083–1086.
- Santiago, V., Rodríguez Hernández, C., Ortega Arenas, L., Ochoa Martínez, D. and Infante Gil, S. (2009): Repellence of white fly adults (*Trialeurodes vaporariorum* West.) to essential oils. *Fitosanidad* 13, 11–14.
- Saviuc, C., Grumezescu, A., Chifiriuc, C., Mihaiescu, D., Hristu, R., Stanciu, G., Oprea, E., Radulescu, V. and Lazar, V. (2011): Hybrid nanosystem for stabilizing essential oils in biomedical applications. *Digest J. Nanomaterials and Biostructures* 6, 1657–1666.
- Schuhmacher, A., Reichling, J. and Schnitzler, P. (2003): Virucidal effect of peppermint oil on the enveloped viruses herpes simplex virus type 1 and type 2 in vitro. *Phytomedicine* 10, 504–510.
- Shakarami, J., Kamali, K. and Moharrampour, S. (2004): Application of *Artemisia aucheri* Boiss as a botanical insecticide, Proc. of the 1st Iranian National Seminar on Development of Agrochemical Industries, Tehran, Iran.
- Sharifian, I., Hashemi, S. M., Aghaei, M. and Alizadeh, M. (2012): Insecticidal activity of essential oil of *Artemisia herba-alba* Asso against three stored product beetles. *Biharian Biologist* 6, 90–93.
- Singh, G., Maurya, S., Lampasona, M. D. and Catalan, C. (2005): Chemical constituents, antimicrobial investigations, and antioxidative potentials of *Anethum graveolens* L. essential oil and acetone extract: Part 52. *J. Food Science* 70, 208–215.
- Tapondjou, A., Adler, C., Fontem, D., Bouda, H. and Reichmuth, C. (2005): Bioactivities of cymol and essential oils of *Cupressus sempervirens* and *Eucalyptus saligna* against *Sitophilus zeamais* Motschulsky and *Tribolium confusum* du Val. *J. Stored Products Research* 41, 91–102.
- Tripathi, A. K., Prajapati, V., Aggarwal, K. K. and Kumar, S. (2001): Insecticidal and ovicidal activity of the essential oil of *Anethum sowa* Kurz against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). *International J. Tropical Insect Science* 21, 61–66.
- Trumble, J. T. (2002): Caveat emptor: safety considerations for natural products used in arthropod control. *American Entomologist* 48, 7–13.
- van Lenteren, J. C. (2000): A greenhouse without pesticides: fact or fantasy? *Crop Protection* 19, 375–384.
- Ward, J. H. (1963): Hierarchical grouping to optimize an objective function. *J. American Statistical Association* 58, 236–244.

- Yang, N.-W., Li, A.-L., Wan, F.-H., Liu, W.-X. and Johnson, D. (2010): Effects of plant essential oils on immature and adult sweetpotato whitefly, *Bemisia tabaci* biotype B. *Crop Protection* 29, 1200–1207.
- Zawislak, G. and Dzida, K. (2012): Composition of essential oils and content of macronutrients in herbage of tarragon (*Artemisia dracunculus* L.) grown in south-eastern Poland. *J. Elementology* 17, 721–729.
- Zorca, M., Gainar, I. and Bala, D. (2009): Isolation and fractional separation of Tarragon essential oil by supercritical fluid. *Analele Universitatii din Bucuresti. Chimie* 1, 21–25.