Persian J. Acarol., 2017, Vol. 6, No. 1, pp. 39–52.
http://dx.doi.org/10.22073/pja.v6i1.23974
Journal homepage: http://www.biotaxa.org/pja

Article

Sublethal effects of *Artemisia annua* L. and *Rosmarinus officinalis* L. essential oils on life table parameters of *Tetranychus urticae* (Acari: Tetranychidae)

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ABSTRACT
The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) is one of the most important agricultural pests of the world. It causes direct and indirect damage on plants which decreases in photosynthesis and crop yield. The effect of sublethal concentrations of *Artemisia annua* L. (Asteraceae) and *Rosmarinus officinalis* L. (Lamiaceae) essential oils were assessed on development and reproduction para-meters of two-spotted spider mite *T. urticae*. Lethal and sublethal concentrations were estimated by fumigant bioassay of essential oils on the adults of *T. urticae*. The raw life history data of all individuals were analyzed according to the age-stage, two-sex life table theory. LC_{30} and LC_{50} of *A. annua* (2.908 and 4.14 µl/80 ml air) and *R. officinalis* (1.339 and 2.006 µl/80 ml air) showed that rosemary essential oil has higher fumigant toxicity against *T. urticae*. Sublethal concentration of the two plant oils led to significant decrease in fecundity, generation time and adult longevity compare to the control. In addition, plant oils decreased the net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and significantly increased doubling time (DT) of *T. urticae* in compare with control. Obtained results indicated that, sublethal concentra-tions of *A. annua* and *R. officinalis* oils could influence on biological indices of *T. urticae*.

KEY WORDS: Asteraceae; Lamiaceae; population growth indices; sublethal dose; two-sex life table; two-spotted spider mite.

PAPER INFO.: Received: 8 September 2016, Accepted: 22 October 2016, Published: 15 January 2017

INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is a cosmopolitan highly polyphagous pest that injures directly and indirectly by decreasing plant photosynthesis and transpiration. (Brandenburg and Kennedy 1987). This pest belongs to the list of serious pests of agricultural crops and ornamentals around the world (Laborda *et al*. 2013). More than 150 of these crops are economically important have been reported as this mite's host (Jeppson *et al*. 1975; Zhang *et al*. 2003; Motazedian *et al*. 2011).

Chemical control has been the main control method against *T. urticae*. Because of long-term use of chemical pesticides against this pest, short life cycle and plentiful progeny, two-spotted spider mite is able to develop resistance to these compounds rapidly (Knowles 1997; van Leeuwen *et al*. 2009; Bugeme *et al*. 2015). Until 2004, spider mites have evolved resistance up to 80 acaricides (DARP 2004) and this leads to using more acaricides frequently to control this pest by some farmers. In addition, the environmental problems caused by overuse of pesticides have been the matter of concern for researches in recent years which promote use of other compounds and strategies. Therefore, alternative methods for control of *T. urticae* like using natural plant-based products have been proposed. Most of these products are environmentally non-persistent and non-toxic to humans (with some exceptions) (Cockayne and Gawkrodger 1997; Hjorther *et al*. 1997), fish (with some exceptions) and wildlife (Wager-Page and Mason 1997; Kumar *et al*. 2000). Essential oils, particularly, have been demonstrated to have a broad array of bioactivities in arthropods, such as toxicity, oviposition deterrence, antifeedant property as well as both general attraction and repellence (Isman 2006; da Camara *et al*. 2015).

Many essential oil compounds were documented to exhibit acute toxic effects against agricultural pests (Hummelbrunner and Isman 2001; Khan *et al*. 2007; Zibaee *et al*. 2010; Tak *et al*. 2015; de Lira *et al*. 2015). Acaricidal activities of different essential oils have been studied against *T. urticae* (Lee *et al*. 1997; Chiasson *et al*. 2001; Martínez-Villar *et al*. 2005; Miresmailli and Isman 2006; Roh *et al*. 2011). Choi *et al*. (2004) has evaluated 53 plant essential oils against *T. urticae* and *Phytoseiulus persimilis* (Acari: Phytoseiidae). Also, the effect of some plant extracts from Asteraceae, including *Achillea millefolium*, *Taraxacum officinale*, *Matricaria chamomilla* and *Salvia officinalis* was examined on biology of *T. urticae* (Tomczyk 1995; Kawka and Tomczyk 2002).

Rosmarinus officinalis L. and *Artemisia annua* L., are mediterranean woody perennial herbs which are an aromatic and a medicinal plant, respectively (Laborda *et al*. 2013; Bilia *et al*. 2014). *Rosmarinus officinalis* essential oil has been formerly investigated for its insecticidal and acaricidial efficacy against a wide range of pests (Lee *et al*. 2001; Miresmailli *et al*. 2006; Laborda *et al*. 2013; Kiran and Prakash 2015). Also, it has been suggested that *A. annua* essential oil has high potential as stored product protectant against insect attack. So that, this oil causes repellency, ovicidal, larvicidal affects in *Callosobruchus maculatus* L. and *Tribolium castaneum* Herbst (Tripathi *et al*. 2000).

In this study effects of *R. officinalis* and *A. annua* essential oils were investigated against *T. urticae* and the sublethal effect of these natural pesticides has been studied on biological characteristics, including mean developmental time, fecundity, survival and adult emergence.

MATERIALS AND METHODS

Essential oils extraction and mite rearing

Artemisia annua and *R. officinalis* at their flowering stage were collected from Karaj, Alborz Province, Iran; then essential oils were extracted (Motazedian *et al*. 2012). Briefly, aerial parts of plants were shade dried and then ground using a grinder of 2 mm diameter mesh. Plant materials were subjected to water distillation for three hours using a Clevenger apparatus. Then, the oil was decanted from the water layer, dried through Na_2SO_4 application, and stored in sealed vials at 4 °C prior starting expriment.

The initial *T. urticae* population was collected from a glasshouse in Karaj, Iran. This population was reared on bean leaves under laboratory conditions at 25 ± 2 °C, 70 ± 5% RH and photoperiod of 16L:8D h.

Bioassay

Fumigant toxicity of plant essential oils was investigated in glass Petri dishes (90 × 20 mm) which were used as an experimental unit. Twenty same aged adults (from both sexes, 1–24 h) from the stock colony were transferred on an excised bean leaf (ca 2 cm diameter) which placed on its dorsal side above the 4-ply wet filter paper (saturated with distilled water) in a Petri dish using a soft paint brush. Five concentrations of each essential oil (2, 2.82, 4, 5.65 and 8 µl/80 ml air for *A. annua* and 1, 1.4, 2, 2.8 and 4 µl/80 ml air for *R. officinalis*) were used in bioassays. Mites were allowed to settle for half an hour before being exposed to the essential oils (Soylu *et al*. 2006). To prevent the direct contact between mites and plant oils, the desired oil quantities were applied on a filter paper (5 × 2 cm) which was fixed on the inner surface of the Petri dishes cap. Then, Petri dishes were sealed with parafilm after pouring the certain amounts of oils on them preventing any essential oils loss. Each concentration (treatment) was replicated three times with 20 adult mites in each replication. The same procedures were used for control but without essential oils. Mortality was recorded 24 h post treatment. Mites incapable of moving after a slight touch with a fine brush were considered as dead.

Life history and survival rate

In order to study the effect of essential oils on the mite life history and survival rate, the adult mites were treated with LC_{30} of *A. annua* and *R. officinalis* essential oils (2.908 and 1.339 µl/80 ml air, as a sublethal dose). After that, the treated adult mites were transfered on leaves for oviposition. After 12 h, females were removed. In each treatment, 100 eggs were monitored daily until hatching. Then hatched larvae were placed individually on bean leaves and developmental time was recorded daily. In addition, survivorships of different stages were recorded daily until death of all adults.

Data analysis

The raw life history data of all individuals were analyzed according to the age-stage, two-sex life table theory (Chi and Liu 1985; Chi 1988, 2005). The means and standard errors of the population parameters were estimated using the bootstrap (1000) method (Huang and Chi 2013). The age-stage specific survival rate (S_{xj}) (where x is the age and j is the stage), age-stage specific fecundity (f_{xj}), age-specific survivorship (l_x), age-specific fecundity (m_x), and (r), intrinsic rate of increase; (λ), finite rate of increase; $(R)_0$, net reproduction rate; and T, (the mean generation time) were calculated accordingly.

Intrinsic rate of increase was estimated using the iterative bisection method from the Euler-Lotka equation (Goodman 1982):

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

with age started from zero. The mean generation time is defined as the length of time that a population needs to increase to R_0-fold of its original size (i.e. $e^{rT} = R_0$ or $\lambda^T = R_0$) at the stable age-stage distribution and is calculated as $T = (ln\ R_0) / r$. The age-stage life expectancy (e_{xj}) is calculated according to Chi and Su (2006). Paired bootstrap method was used to compare the difference among treatments (Using TWOSEX MSChart).

Also, LC_{50} and LC_{30} of toxicity bioassay were determined with Polo-Plus software (version 2).

RESULTS

Probit analysis results indicated that *R. officinalis* essential oil was more toxic than *A. annua* oil against two-spotted spider mite adults (Table 1).

Table 1. Fumigant toxicity of the two essential oils on *Tetranychus urticae*.

Plant	LC_{30}*	LC_{50}	Slop ± SE	χ^2 (df)
Artemisia annua	2.908 (2.173–3.489)†	4.14 (3.445–4.923)	3.419 ± 0.61	2.462 (13)
Rosmarinus officinalis	1.339 (0.937–1.647)	2.006 (1.628–2.434)	2.99 ± 0.578	3.476 (13)

* µl/80 ml air

† Confidence limit of 95%

Obtained results showed that there was no significant difference between the egg ($F_{2,257}$ = 0.996; P = 0.371), larva ($F_{2,244}$ = 0.127; P = 0.881), protonymph ($F_{2,226}$ = 0.121; P = 0.886) and deutonymph ($F_{2,223}$ = 0.6; P = 0.55) developmental stages of the mites treated with two essential oils in compare with Control. In contrast, essential oil treatments reduced the longevity of adult male ($F_{2,69}$ = 9.7; $P < 0.0001$) and female ($F_{2,163}$ = 48.7; $P < 0.0001$) in compare with Control, significantly. Also, the adult preoviposition period (APOP) and total preoviposition period (TPOP) of mites were significantly reduced after treating with essential oils in compare with Control. Minimum APOP (1.13 ± 0.05 days) and TPOP (10.7 ± 0.08 days) were recorded in *R. officinalis* treatment. Both *A. annua* and *R. officinalis* reduced the mite fecundity ($F_{2,163}$ = 43.03; $P < 0.001$) compared with Control, significantly. While, no significant differ-ence was observed between durations of developmental stages of mites treated with the different oils (Table 2).

Table 2. Life history statistics (mean ± SE) (N) of *Tetranychus urticae* exposed to sublethal doses of essential oil of *Artemisia annua* and *Rosmarinus officinalis* in compare with Control.

Treatments	***A. annua***		***R. officinalis***		**Control**	
Parameters	**Mean ± SE**	**N**	**Mean ± SE**	**N**	**Mean ± SE**	**N**
Developmental stages						
Egg	4.53 ± 0.056^{a*}	80	4.4 ± 0.05 ^{a}	85	4.41 ± 0.05 ^{a}	92
Larva	1.55 ± 0.058^{a}	75	1.51 ± 0.056^{a}	81	1.53 ± 0.05 ^{a}	89
Protonymph	1.77 ± 0.05 ^{a}	71	1.77 ± 0.047 ^{a}	80	1.8 ± 0.043^{a}	86
Deutonymph	1.81 ± 0.047 ^{a}	70	1.85 ± 0.041 ^{a}	78	1.78 ± 0.04 ^{b}	86
Female longevity	15.95 ± 0.33 ^{b}	44	16.53 ± 0.22 ^{b}	53	20.33± 0.23	67
Male longevity	12.65 ± 0.24 ^{b}	26	12.64 ± 0.29 ^{b}	25	14.11± 0.35	19
APOP (d)	1.23 ± 0.06 ^{b}	44	1.13 ± 0.05 ^{c}	31	1.56 ±0.06 ^{a}	67
TPOP (d)	10.93 ± 0.11^{b}	44	10.7 ± 0.08 ^{b}	31	11.06 ±0.08	67
Fecundity†	34.64 ± 3.01 ^{b}	44	39.57 ± 2.05 ^{b}	31	71.12 ±1.51	67

* Means within a row sharing the same letter are not significantly different. The SEs were estimated using 10,000 bootstraps and compared using paired bootstrap test based on CI of differences.
† Egg/female

Population growth parameters

Effects of the two plant oils on biological parameters of *T. urtica*e were compared with control (Table 3). *Artemisia annua* and *R. officinalis* oils had reduced R_0 of the mite (15.24 ± 2.15 and 20.97 ± 2.25, respectively) in comparison with control (47.65 ± 3.47), significantly. Also, *T. urticae* had significantly lower R_0 on *A. annua* than other treatment. In both essential oils treatment r value was reduced (0.1970 ± 0.010 and 0.2217 ± 0.008 day^{-1} for *A. annua* and *R. officinalis*, respectively) in compare with Control (0.2575 ± 0.005 day^{-1}). Both *A. annua* and *R. officinalis* oils reduced the mite's finite rates of population increase (1.2178±0.012 and 1.2488±0.01 day^{-1} respectively), in compare with control, significantly (Table 3). Also, fecundity (F) and mean generation time (T) were affected by essential oils application, significantly (Table 3).

Table 3. Mean ± SE of population parameters of *Tetranychus urticae* exposed to sublethal doses of essential oil of *Artemisia annua* and *Rosmarinus officinalis*.

Parameters	***A. annua***	***R. officinalis***	**Control**
r	0.1970±0.010 ^{b*}	0.2217±0.008 ^{b}	0.2575±0.005 ^{a}
λ	1.2178±0.012 ^{b}	1.2488±0.01 ^{b}	1.2937±0.006 ^{a}
F	34.64±3.01 ^{b}	39.57±2.05 ^{b}	71.12±1.51 ^{a}
R_0	15.24±2.15 ^{c}	20.97±2.25 ^{b}	47.65±3.47 ^{a}
T	13.82±0.12 ^{b}	13.7±0.79 ^{b}	15±0.08 ^{a}

* Means within a row sharing the same letter are not significantly different. The SEs were estimated by using 10,000 bootstraps and compared by using paired bootstrap test based on CI of differences.

Effect of two essential oils on age-stage two sex survival rate (s_{xj}) of adult and pre-adult stages are clearly shown on Fig. 1. Age-specific survivorship (l_x), age-specific fecundity (m_x), and age specific maternity ($l_x m_x$) of *T. urticae* exposed to the essential oils in compare with control are shown in Fig. 2.

As Fig. 2 shows, duration of the period in which a female is able to egg laying is decreased after the use of essential oils. Age-stage specific life expectancy (e_{xj}) of *T. urticae* exposed to plant oils in compare with control is shown in Fig. 3.

As Fig. 3 clarified, decrease in *T. urticae* life expectancy is an effect of essential oils treatment. Reduction in age-stage specific reproductive value (v_{xj}) of *T. urticae* exposed to the essential oils showed the reducing potential of this pesticide on two-spotted spider mite reproduction capability (Fig. 4). Duration and amount of reproduction were reduced obviously in *T. urticae* females after the use of two essential oils.

DISCUSSION

Applying the chemical insecticides is not only detrimental to environment but its long time application history also leads to development of resistance among insects (Martínez-Villar *et al*. 2005; Laborda *et al*. 2013). Essential oils and their constituents demonstrate fumigant and contact toxicities towards insects which besides having direct impact of mortality, also have several secondary impacts, such as oviposition, repellency and antifeedancy (Motazedian *et al*. 2011; Gholamzadeh Chitgar *et al*. 2013). Najafabadi *et al*. (2012) demonstrated the effect of three essential oils on *T. urticae.* The LC_{50} values of Lavender, Thyme and Eucalyptus for adult mites were evaluated as 0.65, 1.84 and 2.18 µl/100 ml air, respectively. In this study, the LC_{50} value for *R. officinalis* and *A. annua* were 2.006 and 4.14 µl/80 ml air that shows the lower fumigant toxicity of our plant oils in compare with Lavender, Thyme and Eucalyptus oils against the two spotted spider mite. However, the innate resistance of mite against tested oils is different in various populations that must be considered. Many researches showed that plant essential oils reduced the reproduction capacity of *T. urticae* (El-Gengaihi *et al*. 1996; Gholamzadeh-Chitgar *et al*. 2013).

In the present study, *R. officinalis* and *A. annua* showed significant reduction in fecundity, developmental times and adult longevity that may led to lower damage level to plant, due to shorter feeding time of the pest, and possible disorder in reproductive organs in adult stage. Refaat *et al*. (2002) revealed the effect of two essential oils, *Ocimum basilicum* (Lamiaceae) and *Lavandula officinalis* (Lamiaceae) on *T. urticae* that both essential oils decreased total number of eggs laid by this mite. Similar study by Miresmailli and Isman (2006) showed that rosemary oil repels spider mites and can influence its oviposition behavior. Index *r* has also been recommended together with toxicity assessment to provide more accurate estimate of population-level effect of toxic compounds (Forbes and Calow 1999). Most toxic compounds have an ability to decrease the intrinsic rate of increase (*r*) for some pests (El-Gengaihi *et al*. 1996; Gholamzadeh-Chitgar *et al*. 2013). In our study, *r* reduced significantly at 2.908 and 1.339 µl/80 ml air of *A. annua* and *R. officinalis* essential oils, respectively.

Pietrosiuk *et al*. (2003) showed the decrease in female fecundity and a shortened longevity of *T. urticae* exposed to pyrrolizidine alkaloids, which extracted from *Lithospermum canescens* (Borraginaceae). In this research two essential oils showed significant reduction on life-table parameters like r, R_0, T and λ. The essential oils caused a reduction in longevity, survival and fecundity of *T. urticae* and thereby causes a reduction in *r*. Similar to our results, Martínez-Villar *et al*. (2005) showed that the azadirachtin decreased life table parameter like R_0, λ and T of the two-spotted spider mite. Also, Pietrosiuk *et al*. (2003) founded that pyrrolizidine alkaloids caused a reduction in *r* value of treated *T. urticae* female. Our results showed that both essential oils had a significant effect on the pest fertility. Such effects may relate to induce deformations of ovaries and testes (Desneux *et al*. 2007). However, very few studies have documented potential mechanisms of inhibition of reproduction by essential oil on agricultural pests.

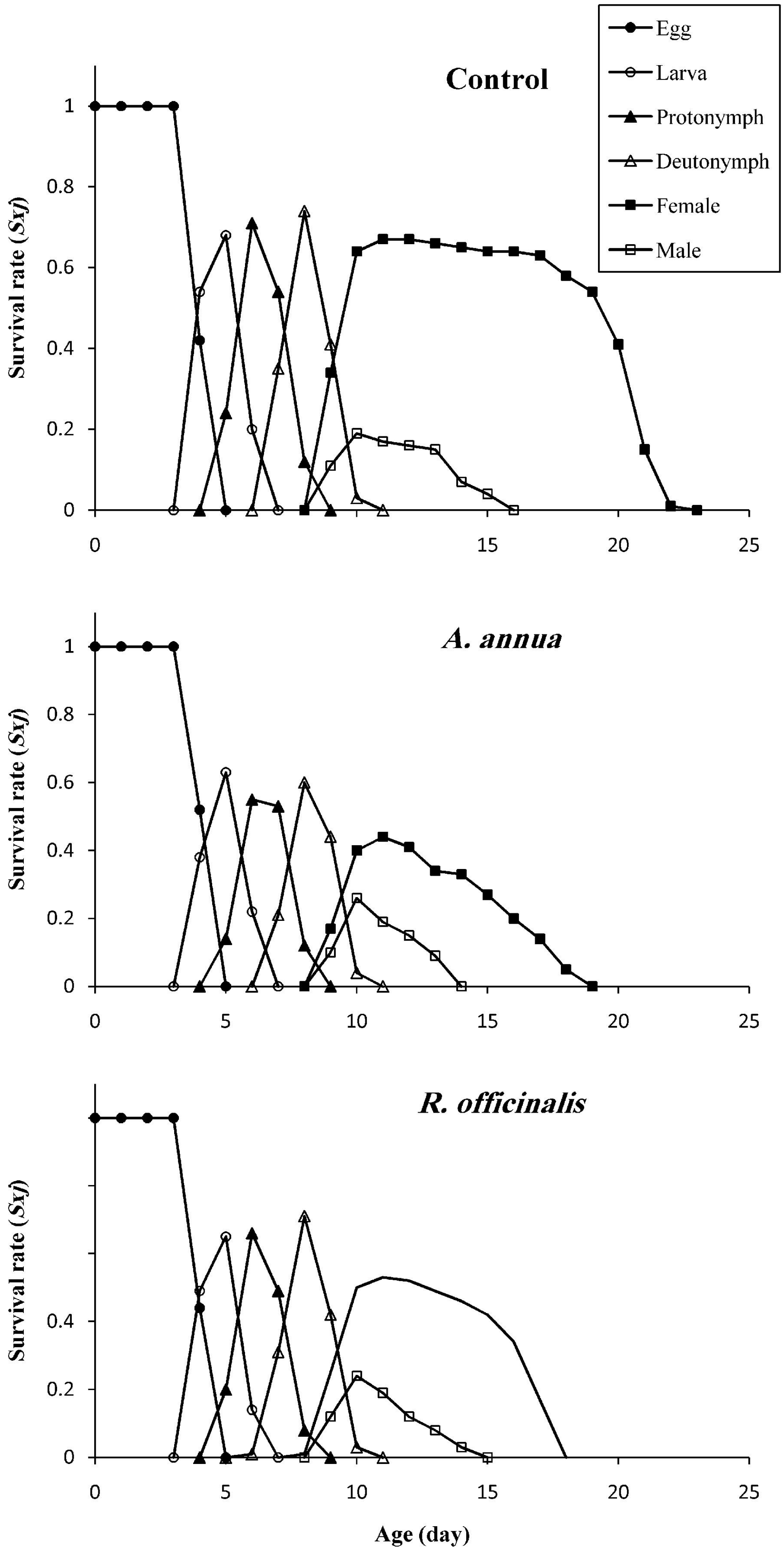

Figure 1. Age-stage two sex survival rate (s_{xj}) of *Tetranychus urticae* exposed to sublethal doses of *Artemisia annua* and *Rosmarinus officinalis* oils.

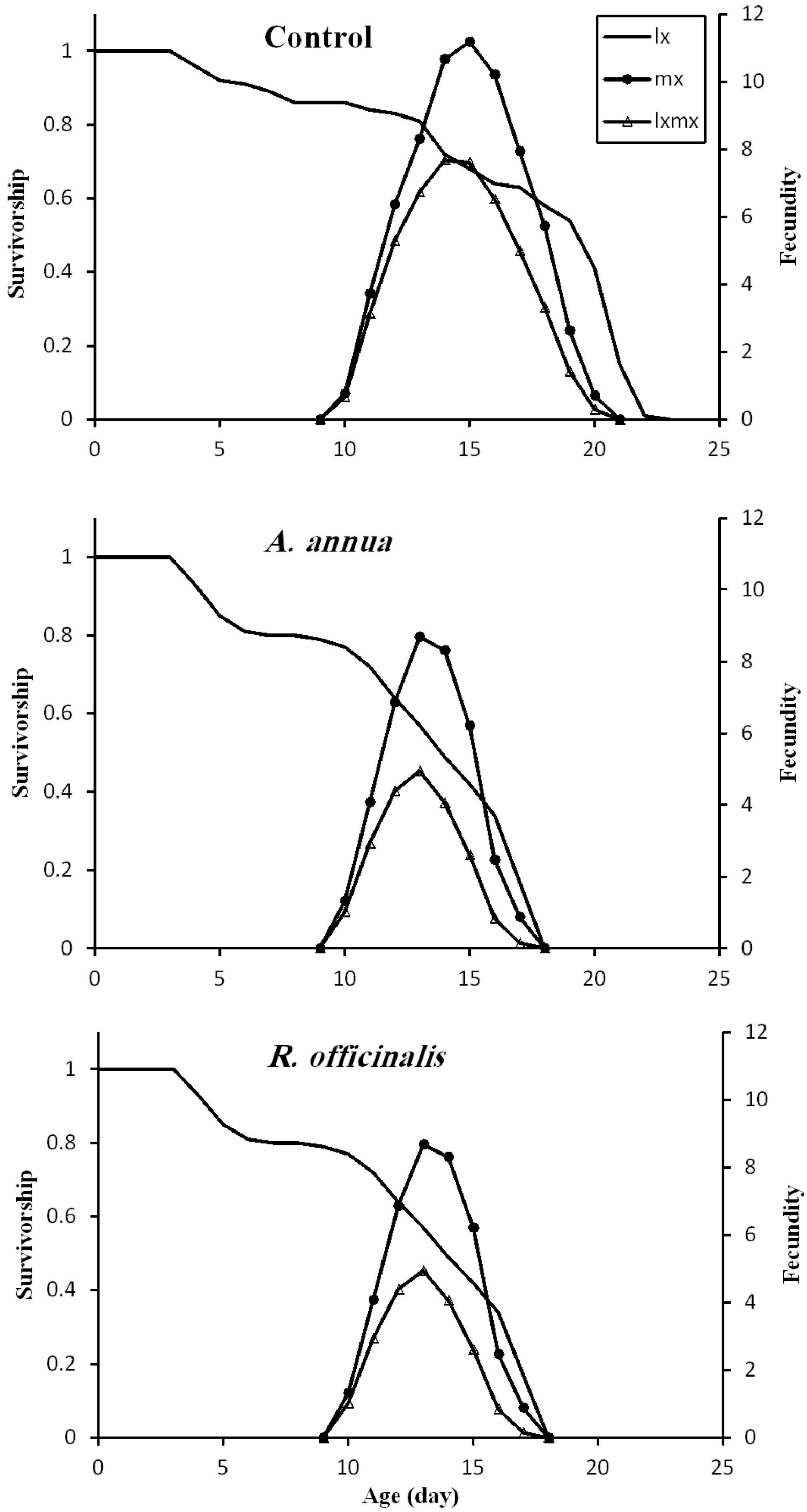

Figure 2. Age-specific survivorship (l_x), age-specific fecundity (m_x), and age specific maternity (l_xm_x) of *Tetranychus urticae* exposed to sublethal doses of *Artemisia annua* and *Rosmarinus officinalis* oils.

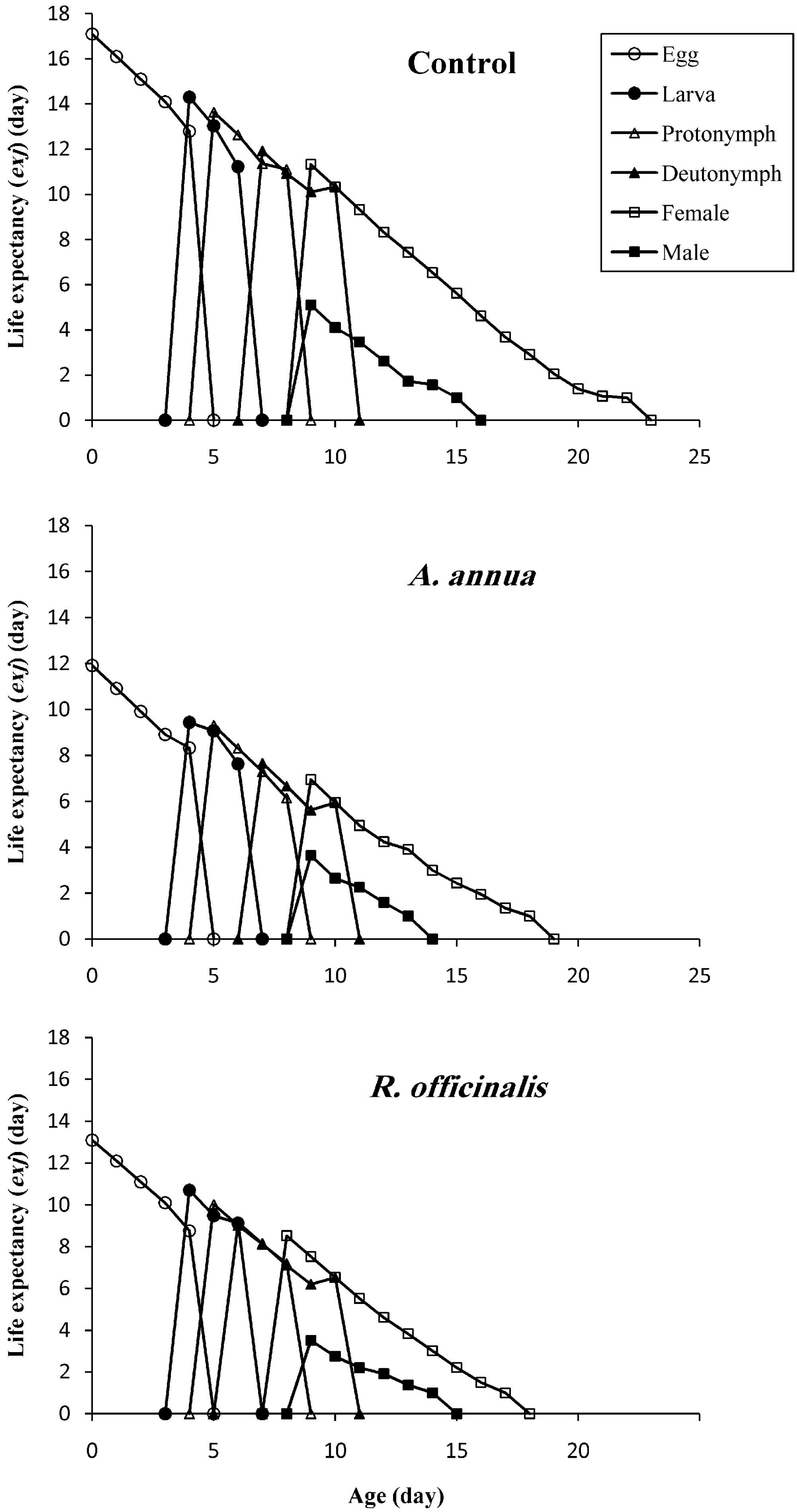

Figure 3. Age-stage specific life expectancy (e_{xj}) of *Tetranychus urticae* exposed to sublethal doses of *Artemisia annua* and *Rosmarinus officinalis* oils.

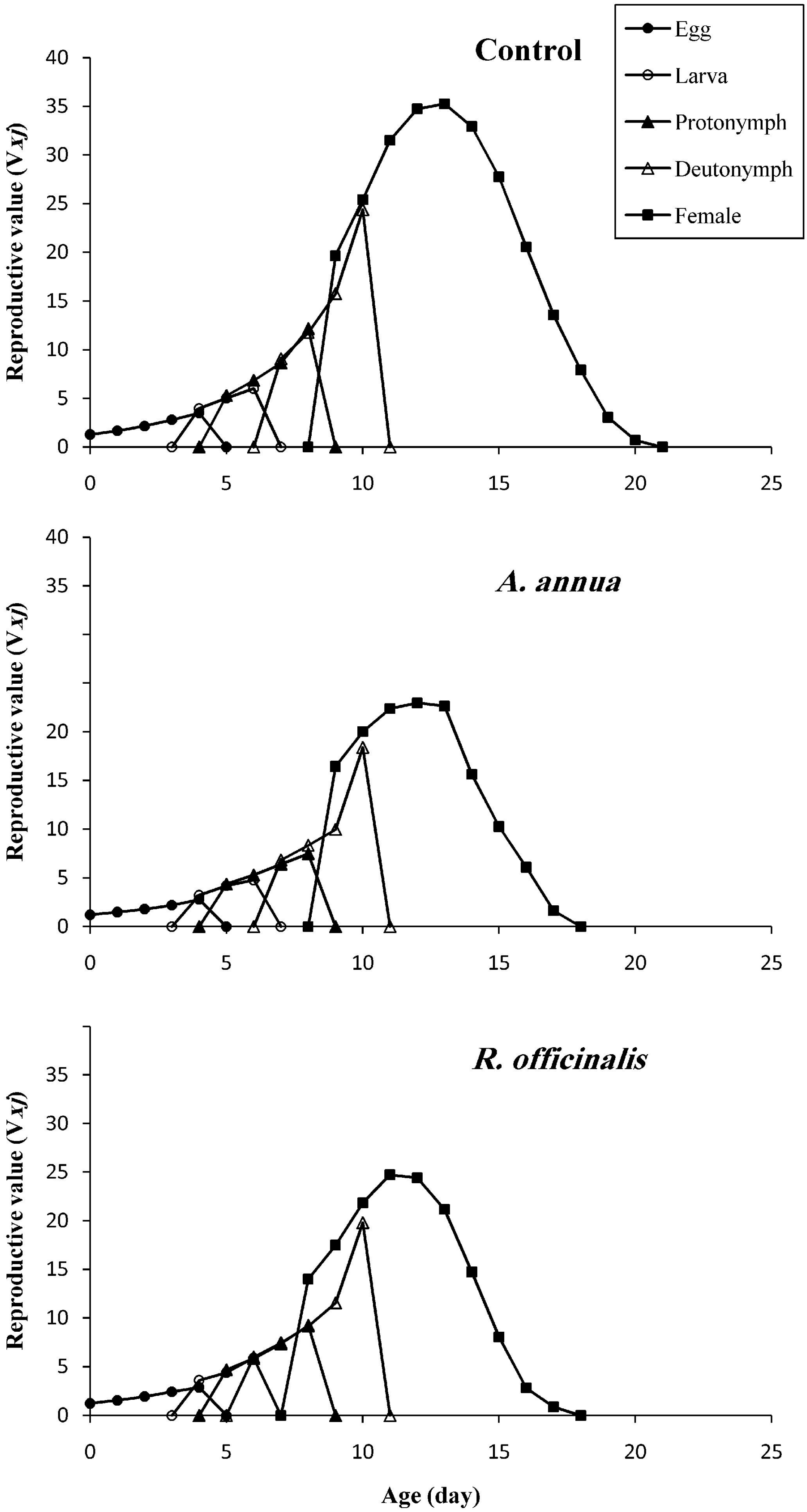

Figure 4. Age-stage specific reproductive value (v_{xj}) of *Tetranychus urticae* exposed to sub lethal doses of *Artemisia annua* and *Rosmarinus officinalis* oils.

Considering the time consuming nature of demographic studies and validity of the laboratory results of IOBC method for determining the effects of the essential oils on *T. urticae* (Oomen *et al*. 1991), the IOBC method could be preferable when limited time is available. However, we prefer to rely on life table study, because it integrates potentially complex interactions among life history indices and provides a more relevant measure of ecological impact of the oils on this pest (Forbes and Calow 1999).

In conclusion, our finding shows that *R. officinalis* and *A. annua* reduces longevity and fecundity of *T. urticae* adults. However, to predict the fate of a treated population over several generations, it is required to consider other important aspects, especially development of resistance to these natural products. Obviously, a reiterated use of the same compound increase the possibility of resistance development in *T. urticae*. Also, semi-field and field studies aiming to evaluate the efficacy of the *A. annua* and *R. officinalis* essential oils are needed in order to obtain more applicable results under field conditions.

ACKNOWLEDGEMENTS

We appreciate University of Tehran, for the financial support of this study.

REFERENCES

Bilia, A.R., Santomauro, F., Sacco, C., Bergonzi, M.C. & Donato, R. (2014) Essential oil of *Artemisia annua* L.: an extraordinary component with numerous anti-microbial properties. *Evidence-Based Complementary and Alternative Medicine*, 159819, doi: 10.1155/2014/159819

Brandenburg, R. & Kennedy, G. (1987) Ecological and agricultural considerations in the management of twospotted spider mite (*Tetranychus urticae* Koch). *Agricultural Zoology Reviews.*2: 185–236.

Bugeme, D.M., Knapp, M., Ekesi, S., Chabi-Olaye, A., Boga, H.I. & Maniania, N.K. (2015) Efficacy of Metarhizium anisopliae in controlling the two-spotted spider mite *Tetranychus urticae* on common bean in screenhouse and field experiments. *Insect science,* 22: 121–128.

Chi, H. (1988) Life-table analysis incorporating both sexes and variable development rates among individuals. *Environmental Entomology*, 17: 26–34.

Chi, H. (2005) TWOSEX-MSChart: a computer program for the age-stage, two-sex life table analysis. Taichung, Taiwan: National Chung Hsing University. Available from: http://140.120 197 (Accessed on 9 Deember 2015).

Chi, H. & Liu, H. (1985) Two new methods for the study of insect population ecology. *Bulletin of the Institute of Zoology, Academia Sinica*, 24: 225–240.

Chi, H. & Su, H.-Y. (2006) Age-stage, two-sex life tables of *Aphidius gifuensis* (Ashmead) (Hymenoptera: Braconidae) and its host *Myzus persicae* (Sulzer) (Homoptera: Aphididae) with mathematical proof of the relationship between female fecundity and the net reproductive rate. *Environmental Entomology*, 35: 10–21.

Chiasson, H., Bélanger, A., Bostanian, N., Vincent, C. & Poliquin, A. (2001) Acaricidal properties of *Artemisia absinthium* and *Tanacetum vulgare* (Asteraceae) essential oils obtained by three methods of extraction. *Journal of Economic Entomology,* 94: 167–171.

Choi, W.-I., Lee, S.-G., Park, H.-M. & Ahn, Y.-J. (2004) Toxicity of plant essential oils to *Tetranychus urticae* (Acari: Tetranychidae) and *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Journal of Economic Entomology*, 97: 553–558.

Cockayne, S.E. & Gawkrodger, D.J. (1997) Occupational contact dermatitis in an aromatherapist. *Contact Dermatitis,* 37: 306–306.

da Camara, C.A., Akhtar, Y., Isman, M.B., Seffrin, R.C. & Born, F.S. (2015) Repellent activity of essential oils from two species of *Citrus* against *Tetranychus urticae* in the laboratory and greenhouse. *Crop Protection*, 74: 110–115.

DARP (2004) Database of arthropods resistance to pesticides. Available from: http://www.pesticideresistance.org/DB/index.html (Accessed on 8 March 2016)

de Lira, C.S., Pontual, E.V., de Albuquerque, L.P., Paiva, L.M., Paiva, P.M.G., de Oliveira, J.V., Napoleão, T.H. & Navarro, D.M.d.A.F. (2015) Evaluation of the toxicity of essential oil from *Alpinia purpurata* inflorescences to *Sitophilus zeamais* (maize weevil). *Crop Protection*, 71: 95–100.

Desneux, N., Decourtye, A. & Delpuech, J-M. (2007) The sublethal effects of pesticides on beneficial arthropods. *Annual Review Entomology*, 52: 81–106.

El-Gengaihi, S., Amer, S. & Mohamed, S. (1996) Biological activity of Thyme oil and Thymol against *Tetranychus urticae* Koch. *Anzeiger für Schädlingskunde*, *Pflanzenschutz*, *Umweltschutz*, 69: 157–159.

Forbes, V.E. & Calow, P. (1999) Is the per capita rate of increase a good measure of population-level effects in ecotoxicology? *Environmental Toxicology and Chemist-ry*, 18: 1544–1556.

Gholamzadeh-Chitgar, M., Khosravi, R., JalaliSendi, J. & Ghadamyari, M. (2013) Sublethal effects of *Thymus vulgaris* essential oil on life-table parameters of two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). *Archives of Phytopathology and Plant Protection,* 46: 781–788.

Goodman, D. (1982) Optimal life histories, optimal notation, and the value of reproductive value. *American Naturalist*, 119: 803-823.

Hjorther, A., Christophersen, C., Hausen, B. & Menne, T. (1997) Occupational allergic contact dermatitis from carnosol, a naturally-occurring compound present in rosemary. *Contact Dermatitis*, 37: 99–100.

Huang, Y.B. & Chi, H. (2013) Life tables of *Bactrocera cucurbitae* (Diptera: Tephritidae): with an invalidation of the jackknife technique. *Journal of Applied Entomology*, 137: 327–339.

Hummelbrunner, L.A. & Isman, M.B. (2001) Acute, sublethal, antifeedant, and synergistic effects of monoterpenoid essential oil compounds on the tobacco cutworm, *Spodoptera litura* (Lep., Noctuidae). *Journal of Agricultural and Food Chemistry*, 49: 715–720.

Isman, M.B. (2006) Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review Entomology*, 51: 45–66.

Jeppson, L.R., Keifer, H.H. & Baker, E.W. (1975) *Mites injurious to economic plants*. University of California Press. Berkeley, California, USA, 614 pp.

Kawka, B. & Tomczyk, A. (2002) Influence of extracts from sage (*Salvia officinalis* L.) on some biological parameters of *Tetranychus urticae* Koch. feeding on Algerian Ivy (*Hedera helix* variegata L.). In: Enkegaard, E. (Ed.), *Proceedings of the joint IOBC/WPRS Working Group "Integrated Control in Protected Crops, Temperate Climate" and IOBC/NRS "Greenhouse, Nursery, & Ornamental Landscape IPM Working Group" at Victoria (British Columbia)*, Canada, 6–9 May 2002, pp. 127–130.

Khan, M., Hossain, M.A. & Islam, M.S. (2007) Effects of neem leaf dust and a commercial formulation of a neem compound on the longevity, fecundity and ovarian development of the melon fly, *Bactrocera cucurbitae* (Coquillett) and the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). *Pakistan Journal of Biological Sciences*, 10: 3656–3661.

Kiran, S. & Prakash, B. (2015) Toxicity and biochemical efficacy of chemically characterized *Rosmarinus officinalis* essential oil against *Sitophilus oryzae* and *Oryzaephilus surinamensis*. *Industrial Crops and Products*, 74: 817–823.

Knowles, C.O. (1997) Mechanisms of resistance to acaricides. In: Sjut, Volkert (Ed.), Molecular mechanisms of resistance to agrochemicals. *Springer*, Berlin, pp. 57–77.

Kumar, A., Dunkel, F.V., Broughton, M.J. & Sriharan, S. (2000) Effect of root extracts of Mexican marigold, *Tagetes minuta* (Asterales: Asteraceae), on six nontarget aquatic macroinvertebrates. *Environmental Entomology*, 29: 140–149.

Laborda, R., Manzano, I., Gamón, M., Gavidia, I., Pérez-Bermúdez, P. & Boluda, R. (2013) Effects of *Rosmarinus officinalis* and *Salvia officinalis* essential oils on *Tetranychus urticae* Koch (Acari: Tetranychidae). *Industrial Crops and Products*, 48: 106–110.

Lee, B.-H., Choi, W.-S., Lee, S.-E. & Park, B.-S. (2001) Fumigant toxicity of essential oils and their constituent compounds towards the rice weevil, *Sitophilus oryzae* (L.). *Crop Protection*, 20: 317–320.

Lee, S., Tsao, R., Peterson, C. & Coats, J.R. (1997) Insecticidal activity of monoterpenoids to western corn rootworm (Coleoptera: Chrysomelidae), two-spotted spider mite (Acari: Tetranychidae), and house fly (Diptera: Muscidae). *Journal of Economic Entomology*, 90: 883–892.

Martínez-Villar, E., Sáenz-De-Cabezón, F.J., Moreno-Grijalba, F., Marco, V. & Pérez-Moreno, I. (2005) Effects of azadirachtin on the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). *Experimental & Applied Acarology*, 35: 215–222.

Miresmailli, S., Bradbury, R. & Isman, M.B. (2006) Comparative toxicity of *Rosmarinus officinalis* L. essential oil and blends of its major constituents against *Tetranychus urticae* Koch (Acari: Tetranychidae) on two different host plants. *Pest Management Science*, 62: 366–371.

Miresmailli, S. & Isman, M.B. (2006) Efficacy and persistence of rosemary oil as an acaricide against twospotted spider mite (Acari: Tetranychidae) on greenhouse tomato. *Journal of Economic Entomology*, 99: 2015–2023.

Moretti, M.D., Sanna-Passino, G., Demontis, S. & Bazzoni, E. (2002) Essential oil formulations useful as a new tool for insect pest control. *AAPs PharmSciTech*, 3: 64–74.

Motazedian, N., Ravan, S. & Bandani, A. (2011) Toxicity and repellency effects of three essential oils against *Tetranychus urticae* Koch (Acari: Tetranychidae). *Journal of Agricultural Science and Technology*, 14: 275-284.

Najafabadi, S.M. (2012) Study on *Thymus vulgaris*, *Lavandula officinalis* and *Eucalyptus camaldulensis* extracts on the two-spotted spider mite. *International Journal of AgriScience*, 2: 228–236.

Oomen, P., Romeijn, G. & Wiegers, G. (1991) Side-effects of 100 pesticides on the predatory mite *Phytoseiulus persimilis*, collected and evaluated according to the EPPO Guideline. *EPPO Bulletin*, 21: 701–712.

Pavela, R. (2008) Insecticidal properties of several essential oils on the house fly (*Musca domestica* L.). *Phytotherapy Research*, 22: 274–278.

Pietrosiuk, A., Furmanowa, M., Kropczyńska, D., Kawka, B. & Wiedenfeld, H. (2003) Life history parameters of the two-spotted spider mite (*Tetranychus urticae* Koch) feeding on bean leaves treated with pyrrolizidine alkaloids. *Journal of Applied Toxicology*, 23: 187–190.

Refaat, M., Momen, F. & Amer, S. (2002) Acaricidal activity of sweet basil and French lavender essential oils against two species of mites of the family Tetranychidae (Acari: Tetranychidae). *Acta Phytopathologica et Entomologica Hungarica*, 37: 287–298.

Roh, H.S., Lim, E.G., Kim, J. & Park, C.G. (2011) Acaricidal and oviposition deterring effects of santalol identified in sandalwood oil against two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). *Journal of Pest Science*, 84: 495 –501.

Soylu, E.M., Soylu, S., Kurt, S. (2006) Antimicrobial activities of the essential oils of various plants against tomato late blight disease agent *Phytophthora infestans*. *Mycopathologia*, 161: 119–128.

Srinivasan, R., Jambulingam, P., Gunasekaran, K. & Boopathidoss, P. (2008) Tolerance of house fly, *Musca domestica* L. (Diptera: Muscidae) to dichlorvos (76% EC) an insecticide used for fly control in the tsunami-hit coastal villages of southern India. *Acta Tropica*, 105: 187–190.

–Tak, J.H., Jovel, E. & Isman, M.B. (2015) Comparative and synergistic activity of *Rosmarinus officinalis* L. essential oil constituents against the larvae and an ovarian cell line of the cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae). *Pest Management Science*, 72(3): 474–480.

Tripathi, A., Prajapati, V., Aggarwal, K., Khanuja, S. & Kumar. S. (2000) Repellency and toxicity of oil from *Artemisia annua* to certain stored-product beetles. *Journal of Economic Entomology*, 93: 43–47.

Van Leeuwen, T., Vontas, J., Tsagkarakou, A., 2009. Mechanisms of acaricide resistance in the two spotted spider mite Tetranychus urticae. In: Ishaaya, I. & Horowitz, A.R. (Eds.), *Biorational Control of Arthropod Pests*. Springer, The Netherlands, pp. 347–393.

Wager-Pagé, S.A. & Mason, J.R. (1996) Ortho-aminoacetophenone, a non-lethal repellent: The effect of volatile cues vs. direct contact on avoidance behavior by rodents and birds. *Pesticide Science*, 46: 55–60.

Zhang, Q.H., Schlyter, F., Battisti, A., Birgersson, G. & Anderson, P. (2003) Electrophysiological responses of *Thaumetopoea pityocampa* females to host volatiles: implications for host selection of active and inactive terpenes. *Anzeiger für Schädlingskunde*, 76: 103–107.

Zibaee, I., Bandani, A., Jalali Sendi, J., Talaei, H. & Kouchaki, B. (2010) Effects of *Bacillus thuringiensis* var. kurstaki and medicinal plants on *Hyphantria cunea* Drury (Lepidoptera: Arctiidae). *Invertebrate Survival Journal*, 7: 251–261.

اثرات زیرکشندهٔ اسانس‌های *Artemisia annua* L. و *Rosmarinus officinalis* L. بر فراسنجه‌های جدول زیستی *Tetranychus urticae* (Acari: Tetranychidae)

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چکیده

کنهٔ تارتن دولکه‌ای *Tetranychus urticae* Koch (Acari: Tetranychidae) یکی از مهم‌ترین آفات کشاورزی در سراسر جهان به شمار می‌آید. این آفت خسارت‌های مستقیم و غیرمستقیمی روی گیاهان ایجاد می‌کند که باعث کاهش فتوسنتز و عملکرد محصول آن‌ها می‌شود. در مطالعه حاضر، اثر غلظت‌های زیرکشندهٔ اسانس دو گیاه *Artemisia annua* L. (Asteraceae) و *Rosmarinus officinalis* L. (Lamiaceae) روی فراسنجه‌های نمو و تولیدمثلی کنه تارتن دولکه‌ای *T. urticae* مورد ارزیابی قرار گرفته است. غلظت‌های کشنده و زیرکشندهٔ دو اسانس با زیست‌سنجی سمیت تدخینی آن‌ها روی کنه‌های بالغ برآورد شدند. داده‌های خام مربوط به اطلاعات جدول زیستی کنه با استفاده از روش جدول زیستی دوجنسی ویژه سن- مرحله مورد تجزیه و تحلیل قرار گرفتند. LC_{30} و LC_{50} اسانس‌های *A. annua* (به ترتیب ۲/۹۰۸ و ۴/۱۴ میکرولیتر بر ۸۰ میلی‌لیتر هوا) و *R. officinalis* (به ترتیب ۱/۳۳۹ و ۲/۰۰۶ میکرولیتر بر ۸۰ میلی‌لیتر هوا) نشان داد که اسانس گیاه رزماری سمیت تدخینی بیشتری روی کنه *T. urticae* دارد. دز زیرکشنده هر دو اسانس منجر به کاهش معنی‌دار زادآوری، مدت زمان یک نسل و طول عمر بالغ‌ها در مقایسه با شاهد شد. همچنین، هر دو اسانس میزان خالص تولیدمثل (R_0)، میزان ذاتی افزایش جمعیت (r) و میزان متناهی افزایش جمعیت (λ) را کاهش و زمان دو برابر شدن جمعیت (DT) *T. urticae* را در مقایسه با شاهد به طور معنی‌داری افزایش دادند. نتایج به دست آمده نشان داد که غلظت‌های زیرکشندهٔ اسانس‌های *A. annua* و *R. officinalis* می‌توانند شاخص‌های زیستی کنهٔ *T. urticae* را تحت تاثیر قرار دهند.

واژگان کلیدی: Asteraceae؛ Lamiaceae؛ شاخص‌های رشد جمعیت؛ دز زیرکشنده؛ جدول زیستی دو جنسی؛ کنهٔ تارتن دولکه‌ای.

اطلاعات مقاله: تاریخ دریافت: ۱۳۹۵/۶/۱۸، تاریخ پذیرش: ۱۳۹۵/۸/۱، تاریخ چاپ: ۱۳۹۵/۱۰/۲۶