J. Crop Prot. 2020, 9 (1): 41-55

Research Article

Influence of low-lethal concentrations of thiamethoxam on biological characteristics of *Neoseiulus californicus* (Acari: Phytoseiidae)

Mohammadreza Havasi[1], Katayoon Kheradmand[1*], Hadi Mosallanejad[2] and Yaghoub Fathipour[3]

1. Department of Entomology and Plant Pathology, Aburaihan Campus, University of Tehran, Tehran, Iran.
2. Iranian Research Institute of Plant Protection, Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.
3. Department of Entomology, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran.

Abstract: For successful implementation of integrated pest management (IPM) programs, having knowledge on lethal and low-lethal effects of pesticides on natural enemies is necessary. The present study evaluated the low-lethal effect of thiamethoxam on life table parameters of the subsequent generation of the predatory mite, *Neoseiulus californicus* McGregor (Acari: Phytoseiidae) fed on *Tetranychus urticae* Koch under laboratory conditions. The low-lethal concentrations LC_5, LC_{10} and LC_{20} were determined based on a dose-effect assay. The raw data were analyzed based on age-stage two sex life table analysis. Exposure to the low-lethal concentrations of thiamethoxam had no significant effects on developmental time of offspring of treated mites. Compared with control treatment, the oviposition period of treated mites with LC_5, LC_{10} and LC_{20} decreased significantly. The highest and lowest values of total fecundity were obtained at control (35.3 eggs/female/day) and LC_{20} (23.6 eggs /female/day), respectively. The net reproductive rate (R_0) decreased with increasing dose from LC_5 (22.6 offspring) to LC_{20} (15.0 offspring). The intrinsic rate of increase (r) and finite rate of increase (λ), were not affected by increasing concentrations. The mean generation time (T) decreased significantly at upper dose (LC_{20} = 13.2 d), compared with control (14.7 d). In consequence, the low-lethal concentration influences of thiamethoxam in combination with *N. californicus* in order to design management programs of *T. urticae* are discussed.

Keywords: predatory mite, LC_{50}, *Tetranychus urticae*, toxicity, life-table

Introduction

The two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae), is one of the most important pests found in ornamental, agricultural and horticultural crops such as cucumber, bean, eggplant, soybean (Sedaratian *et al*., 2011; Khanamani *et al*., 2013; Maleknia *et al*., 2016). Plant photosynthesis is prevented by feeding of this pest from sap, also producing silk webbing (Huffaker *et al*., 1969; Nachman and Zemek, 2003). Great efforts are being made every year to cope with this pest (Watson, 1964; Aydemir and Toros, 1990). Chemical control

---

Handling Editor: Ali Asghar Talebi

---

[*] **Corresponding authors**, e-mail: kkheradmand@ut.ac.ir
Received: 29 April 2019, Accepted: 13 October 2019

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

is the primary strategy for IPM programs due to its, cost-effectiveness, rapidity and ease of use (Zhao, 2000).

A single chemical control method against pests cannot in itself be successful (Kaplan *et al*., 2012), but knowledge of the effects of pesticides on biological control agents is necessary for successful implementation of integrated pest management (IPM) programs (Hamedi *et al*., 2010). Spider mites are difficult to control with miticides (Naher *et al*., 2005) as a result of inaccessibility to lower leaf surface, short lifespan, high reproductive capacity (Cranham and Helle, 1985), which can lead to rapid population growth (Nauen *et al*., 2001). Biological control using natural enemies is an alternative method to chemical control of these pests in agricultural systems (Lewis *et al*., 1997; Barbosa, 1998).

Phytoseiid predators are effective natural enemies of spider mites (McMurtry *et al*., 2013). The predator mite, *Neoseuilus californicus* McGregor (Acari: Phytoseiidae) is a successful species in the control of mites in fields and greenhouses and feeds on Tetranychidae and Tarsonemidae (Castagnoli and Simoni, 1999). This species of phytoseiid, can also feed and reproduce on small arthropod prey or pollen (Khanamani *et al*., 2017).

Neoseiulus californicus prefers to prey on spider mites, however, it also has the ability to prey on other tetranychid species, as well as on other pest mites (Swirski *et al*., 1970; McMurtry *et al*., 2013). Numerous studies have shown that the predatory mites by themselves cannot maintain the population of spider mites under the economic injury level , although their effectiveness as predatory mites for biological control of *T. urticae* has been proven (Helle and Sabelis, 1985; Greco *et al*., 1999, 2005; Alzoubi and Cobanoglu, 2007).

Integration of biological and chemical control is the fundamental tenet and this integration include reducing pesticide use, application of selective pesticides, and modifying natural enemies to reduce their susceptibility to pesticides (Newsom *et al*., 1976; Croft, 1990; Greathead, 1995; Biondi *et al*., 2012; Roubus *et al*., 2014). However, it is important to reduce the usage of pesticides and select products which have low negative impact on biological control agents (Isman, 2000; Hassan and Van De Veire, 2004). Therefore, the combination of using suitable insecticides, along with biological control agents has been widely recommended as an important part of IPM strategies (Elzen, 2001).

Studies that only consider the lethal effects may underestimate the negative effects of pesticides on natural enemies (Galvan *et al*., 2005) and chemicals with minimal toxicity to natural enemies have been applied in integrated pest management programs (Croft, 1990). Demographic toxicology has been considered as a better measure of response to toxicants than individual life history traits (Forbes and Calow, 1999). By using ‘population growth rate’, it is possible to more accurately measure the toxicity of pesticides on useful organisms (Kim *et al*., 2004). Neonicotinoids are presently well-known for their non-target effects on predatory mites and capability to cause spider mite flare-ups in diverse ecosystems (Raupp *et al*., 2004; Beers *et al*., 2005; Szczepaniec *et al*., 2011; Beers and Schmidt, 2014; Duso *et al*., 2014 *et al*). At the same time, these insecticides are chemically similar to nicotine, thus they act antagonistically to insect nicotine acetylcholine receptors (Nauen *et al*., 2003), although they reduce the impacts of insect pests, they can also affect the population levels and dynamics of biological-control agents in agro-ecosystems (Desneux *et al*., 2007; Biondi *et al*., 2012; Guedes *et al*., 2016).

Thiamethoxam, IUPAC name 3-(2-Chloro-thiazol-5-ylmethyl)-5-methyl-(1, 3, 5) oxadiazinan-4-yldene-N-nitroamine, is a second generation neonicotinoid possessing stomach and contact activity, nervous system and inhibits feeding reflex (Maienfisch *et al*., 2001; Torres *et al*., 2003). This

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

insecticide is presently one of the most effective chemicals for the control of sucking pests (Sharma and Lal, 2002). It is commercially available with the common name Actara® (WG25%). Many studies have investigated the lethal and low-lethal effects of pesticides on phytoseiid mites (Çobanoğlu and Alzoubi, 2008; Hamedi *et al.*, 2009; Lima *et al.*, 2013; Alinejad *et al.*, 2014, 2016). However, there are few studies about the low-lethal effects of this insecticide on predatory arthropods such as *N. californicus* (Poletti *et al.*, 2007). Due to the importance of the predator *N. californicus* for integrated pest-management programs (IPM), and the overuse of neonicotinoid insecticides for the control of insect pests, studies to assess the impacts of insecticides on biological and population parameters of this mite are essential to support IPM programs.

Therefore, the present study aimed to understand the low-lethal concentrations of thiamethoxam on pre-imaginal developmental period, adult longevity, fecundity and demographic parameters of *N. californicus*, using the age-stage, two-sex life table to predict this neonicotinoid insecticide potential in combination with one of the effective natural enemies of *T. urticae*.

Materials and Methods

Biological material

The initial stock of *N. californicus* (Spical®) was provided from the Giah Bazr Alvand Company, an agent of the Koppert Company (Tehran, Iran) and reared in the laboratory on kidney bean *Phaseoulus vulgaris* L. plants infested with *T. urticae*. The two-spotted spider mites were obtained from infested plants in Pakdasht (South Eastern part of Tehran) and were released on the kidney bean plants under greenhouse conditions of 25 ± 2 °C, 60 ± 5% RH and a photoperiod of 16:8 (L: D) hr. The predator rearing arenas were made according to McMurtary and Scriven (1965) method and were stored in a growth chamber at 25 ± 2 °C 65 ± 5% RH, and16: 8 (L: D) hr. Bean leaves infested with *T. urticae* were added daily to each arena as food source.

Insecticide solutions

A thiamethoxam-based commercial product, Actara® 25WG (Syngenta Crop Protection), was diluted with distilled water. In toxicity bioassays, the highest tested dose was specified based on the recommended field concentration, 12.5-50 g AI Ha^{-1}, and other five reduced concentrations (1500, 1660, 1800, 1990, and 2200 µg a.i./ml) were chosen to emulate lower concentrations.

Concentration-response bioassay

A modified leaf dip method (Helle and Overmeer, 1985) was used to determine the response of *N. californicus* adults to different concentrations of thiamethoxam (the mortality covering the range of 10-90%. Fresh leaf discs of bean (4 cm diameter) were dipped for 15 s into thiamethoxam solutions, and then were dried for 3 hour at room conditions. Control leaf discs were dipped in distilled water only. In the next stage, 20 same-aged (24 h-old) adult predatory mites (male and female) were placed on the treated leaf discs for each concentration (LC_5, LC_{10} and LC_{20}) using a soft pointed brush. Mite mortality was assessed after 24 h. The low-lethal concentrations including LC_5, LC_{10}, and LC_{20} were determined using a probit procedure (IBM SPSS, Version 19.0). Each concentration was replicated four times. All experiments were conducted in the laboratory at 25 ± 2 °C, 65 ± 5% RH and a photoperiod of 16: 8 (L: D) hour.

The *T. urticae* population, were maintained in greenhouse conditions at 25 ± 2 °C, 60 ± 5% RH, and a photoperiod of 16:8 (L: D) h.

Life-Table Assay

In order to evaluate thelow-lethal effects of thiamethoxam on *N. californicus*, after treatment (modified leaf dip method; Helle and Overmeer, 1985) of bean leaf discs with low-lethal concentrations (including LC_5, LC_{10} and LC_{20}), and distilled water, allowed to dry for 3 h. Then forty-five same-aged females (24 h-old) were transferred on the treated and untreated leaf discs of bean. After

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

24 h, surviving females were separately moved onto the untreated leaf discs (3 cm in diameter). After 24 h, one laid egg was saved in each experimental arena (45 replications for each concentration). In the next procedure, all saved eggs were checked daily and the development time, longevity, oviposition period and fecundity rate until death of the last mite, was recorded. In order to study the fecundity and reproduction parameters, females were coupled with males that were selected from the stock colony in the Petri-dishes. To provide an ample food supply in treatments, 4-6 prey larva and nymph (4-5 times per day) were added as a food source for the immature and adult stages of this predatory mite, respectively. All Petri dishes were checked daily and the information of adult mites such as survival, reproductive durations, adult longevity, fecundity, along with population growth parameters were recorded.

Statistical analysis

The population growth parameters (net reproductive rate [R_0], intrinsic rate of natural increase [r], finite rate of increase [λ], and mean generation time [T]) (Fathipour and Maleknia, 2016), also the age-stage specific survival rate (s_{xj}) (where x = age in days and j = stage); the age-specific survival rate (l_x); the age specific fecundity (m_x); age-stage fecundity of female (f_{xj}) of *N. californicus* were calculated with age stage, two-sex life table (Chi and Liu, 1985; Chi, 1988) using the computer program of TWO-SEX_Ms Chart program (Chi, 2016). Comparisons of statistical differences among means of parameters related to development, as well as fecundity with the Tukey-Kramer procedure was carried out using SAS (SAS Institute, 2002). The means of the latter parameters in population growth parameters between different treatments were compared using paired bootstrap test (Riahi *et al.*, 2017; Khanamani *et al.*, 2017).

Results

Concentration-response bioassay

The regression equation of concentration-mortality was Y = -1.52 + 2.03X [Y = mortality (probit), X = concentration (µg/ml)]. As shown in Table 1, the estimated LC_{50} for the predatory mite was 1822 µg a.i./ml while no mortality was recorded for the control (Table 1). In addition, the values of LC_5, LC_{10}, and LC_{20} were 1449, 1525 and 1622 µg a.i./ml, respectively.

Development time, longevity and total life span

Effects of different concentrations of thiamethoxam on development time of male and female *N. californicus* are shown in Table 2. The time required for *N. californicus* eggs to hatch was 1.18 and 1.24 days for the untreated males and females, respectively (F = 0.1; df = 3, 36; P = 0.96 for male, F = 0.13; df = 3, 112; P = 0.94 for female). The number of days to complete larval stage in male and female were not significantly affected by low-lethal concentrations (male: F = 0.41; df = 3, 36; P = 0.74, Female: F = 0.69; df = 3, 112; P < 0.56). Protonymphal (male: F = 0.45; df = 3, 36; P = 0.71, Female: F = 0.23; df = 3, 112; P = 0.87) and deutonymph (male: F = 0.1; df = 3, 36; P = 0.95, Female: F = 0.01; df = 3, 112; P = 0.99) stage duration of males and females were not significantly different among the treatments. Longevity (F = 907.3; df = 3, 112; P < 0.0001) and total life span (F = 261.3; df = 3, 112; P < 0.0001) of treated females was significantly different from the control. Low-lethal concentrations (LC_5, LC_{10} and LC_{20}) significantly reduced longevity and total lifespan of both sexes compared to control treatment. The longest and the lowest female adult longevity (longest: 27.28 d for control; lowest: 19.07 d for LC_{20}), as well as total life span (longest: 32.10 d for control; lowest: 24.07 d for LC_{20}) were observed in control and LC_{20} treatment, respectively (Table 2).

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

Table 1 Probit analysis for the concentration–mortality response of thiamethoxam on adult females and males of *Neoseiulus californicus*.

Probit values	LC_5	LC_{10}	LC_{20}	LC_{50}	LC_{90}	Slope ± SE	df	x^2	*P*	n
LC value	1449	1525	1622	1822	2190	2.06 ± 0.35	4	1.67	0.64	480
95% upper limits	1505	1575	1664	1865	2290					
95% lower limits	1374	1460	1570	1790	2119					

20 individuals per replicate, four replicates per concentration, six concentrations per assay.

Table 2 Mean (± SE) female and male development time of *Neoseiulus californicus*for control and different concentrations of thiamethoxam.

Parameter	Control	LC_5	LC_{10}	LC_{20}
Male				
Egg duration (day)	1.18 ± 0.12^a	1.20 ± 0.13^a	1.25 ± 0.16^a	1.27 ± 0.14^a
Larva duration (day)	1.09 ± 0.09^a	1.10 ± 0.10^a	1.12 ± 0.12^a	1.00 ± 0.00^a
Protonymph (day)	1.17 ± 0.12^a	1.40 ± 0.16^a	1.37 ± 0.18^a	1.37 ± 0.15^a
Deutonymph (day)	1.27 ± 0.14^a	1.30 ± 0.15^a	1.39 ± 0.17^a	1.37 ± 0.16^a
Male longevity (day)	20.27 ± 0.45^a	19.00 ± 0.47^a	15.88 ± 0.55^b	14.64 ± 0.43^c
Total life span (day)	25.00 ± 0.49^a	24.00 ± 0.49^a	21.00 ± 0.76^b	19.64 ± 0.45^c
Female				
Egg duration (day)	1.24 ± 0.08^a	1.24 ± 0.08^a	1.30 ± 0.09^a	1.30 ± 0.09^a
Larva duration (day)	1.03 ± 0.03^a	1.07 ± 0.05^a	1.13 ± 0.06^a	1.07 ± 0.05^a
Protonymph (day)	1.23 ± 0.08^a	1.24 ± 0.08^a	1.29 ± 0.09^a	1.32 ± 0.09^a
Deutonymph (day)	1.31 ± 0.09^a	1.31 ± 0.09^a	1.30 ± 0.12^a	1.32 ± 0.11^a
Female longevity (day)	27.28 ± 0.11^a	26.07 ± 0.13^b	22.70 ± 0.13^c	19.07 ± 0.11^d
Total lifespan (day)	32.10 ± 0.18^a	30.93 ± 0.25^b	27.73 ± 0.25^c	24.07 ± 0.19^d

Means followed by the same letters in the same row are not significantly different (Tukey-kramer, $P \leq 0.05$).

Reproduction

Reproductive periods and total fecundity of offspring of the treated females is shown in Table 3. There was no significant effect on adult pre-oviposition period (APOP) ($F = 1.94$, $P = 0.12$, $df = 3, 112$) as well as total pre-oviposition period (TPOP) ($F = 0.77$, $P = 0.51$, $df = 3, 112$) of *N. californicus* associated with thiamethoxam (Table 3).The mean total fecundity for LC_5 was 34.38 offspring/individual and was closer to control (35.31 offspring/individual) while LC_{20} was significantly lower (23.61 offspring/individual) ($F = 159.86$, $P < 0.0001$, $df = 3,112$) than the other treatments. The treatment with different concentration of thiamethoxam demonstrated a significant change in the oviposition period, compared with the control treatment, such that there was a variation from 13.57 (LC_{20}) to 21.86 (for control) days in higher concentration and un-treated mites ($F = 1291.2$, $P < 0.0001$, $df = 3, 112$) (Table 3).

Population growth parameters

The life-table parameters of offspring of treated females are shown in Table 4. The gross

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

reproduction rate (*GRR*) varied from 17.64 (for LC_{20}) to 27.18 (for control) offspring/individual (Table 4). The lowest value of *GRR* as well as R_0 (net reproductive rate) was obtained for the mites exposed to the LC_{20} treatment. The intrinsic rate of increase (r) and finite rate of increase (λ) were not significant. The mean generation time was longest in control (14.74 d); followed by LC_{10} (13.95 d) and LC_{20} (13.28 d) treatments (Table 4).

Survival and Fecundity

Age-specific survivorship (l_x), age-specific fecundity (m_x), and age-stage fecundity of female (f_{xj}) *N. californicus* at different concentrations of thiamethoxam are shown in Figure 1. Total lifetime for the untreated mites was 35 days, 33, 31 and 26 days for LC_5, LC_{10} and LC_{20} treatments, respectively (Fig. 1). In addition, the maximum values of m_x were approximately 1.61 eggs/female/day for mites treated with LC_5 treatment, which was on day 25 of the lifespan (Fig. 1). Maximum value of m_x for untreated mites, was 1.42 eggs/female/day that was observed on day 24 of life span. However, maximum values of m_x for LC_{10} and LC_{20} treatments were approximately 1.60 and 1.38 eggs/female/day respectively, which occurred on days 21 and 14 (Fig. 1). The age-stage specific survival rates (*sxj*) of *N. californicus* in treatments are plotted in Figure 2. Overlap between different stages of developmental periods, was observed among the individuals (A-D) (Fig. 2).

Table 1 Mean (± SE) reproductive period and total fecundity of offspring from females of *Neoseiulus californicus* treated with low-lethal concentrations of thiamethoxam and distilled water (CK).

Parameter	Control	LC_5	LC_{10}	LC_{20}
Oviposition period (day)	21.86 ± 0.08^a	20.66 ± 0.09^b	17.42 ± 0.11^c	13.57 ± 0.12^d
APOP (day)[1]	2.28 ± 0.08^a	2.28 ± 0.08^a	2.23 ± 0.07^a	2.52 ± 0.12^a
TPOP (day)[2]	7.12 ± 0.17^a	7.14 ± 0.21^a	7.27 ± 0.22^a	7.51 ± 0.23^a
Total fecundity (offspring/individual)	35.31 ± 0.37^a	34.38 ± 0.43^a	29.62 ± 0.49^b	23.61 ± 0.38^c

Means followed by the same letters in the same row are not significantly different (Tukey-Kramer, $P \leq 0.05$).

[1] APOP: Adult pre-oviposition period, [2] TPOP: Total pre-oviposition period.

Table 2 Life table parameters (mean ± SE) of *Neoseiulus californicus* at different concentrations of thiamethoxam and control treatment.

Parameters	Control	LC_5	LC_{10}	LC_{20}
r (day^{-1})	0.2116 ± 0.010^a	0.2136 ± 0.009^a	0.2166 ± 0.009^a	0.2036 ± 0.010^a
λ (day^{-1})	1.2357 ± 0.012^a	1.2382 ± 0.012^a	1.2419 ± 0.011^a	1.2259 ± 0.012^a
R_0 (offspring/individual)	22.7400 ± 2.527^a	22.6500 ± 2.468^a	20.6500 ± 2.101^a	15.0200 ± 1.719^b
GRR (offspring/individual)	27.1800 ± 2.162^a	27.1100 ± 2.016^a	24.7900 ± 1.676^a	17.6400 ± 1.593^b
T^* (day)	14.7400 ± 0.258^a	14.5800 ± 0.273^a	13.9500 ± 0.265^a	13.2800 ± 0.213^b

The SE were estimated by using 100,000 bootstraps. The means followed by the same letter in each row are not significantly different using paired bootstraps test at the 5% significance level.

Abbreviations: r: intrinsic rate of increase; λ: finite rate of increase; R_0: net reproductive rate; *GRR*: Gross reproductive rate; T: mean generation time.

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

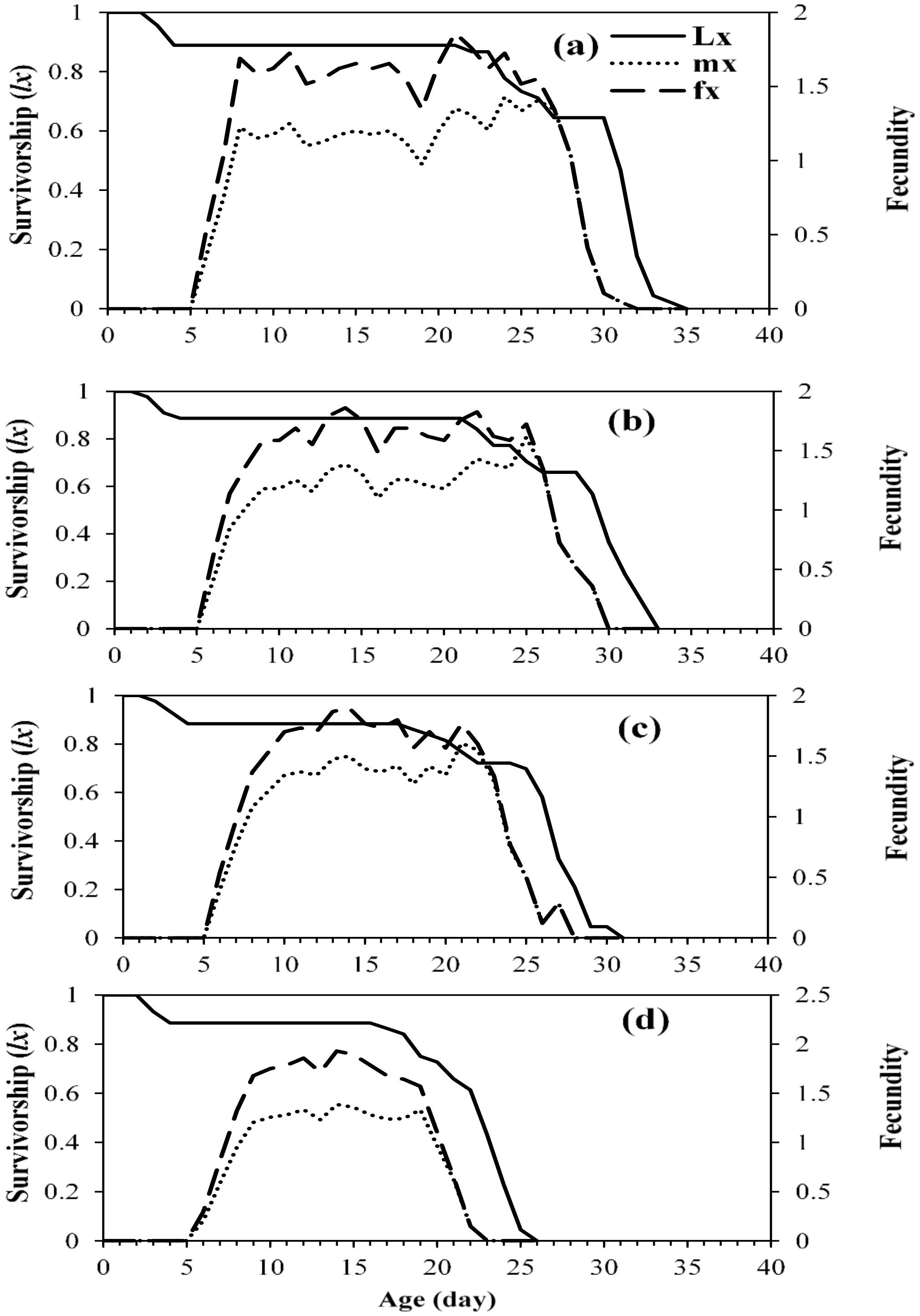

Figure 1 Age-specific survivorship (l_x), age-stage fecundity of female (f_{xj}), and age-specific fecundity (m_x) of *Neoseiulus californicus* for control and different concentrations of thiamethoxam: (a) Control, (b) LC_5, (c) LC_{10}, (d) LC_{20}.

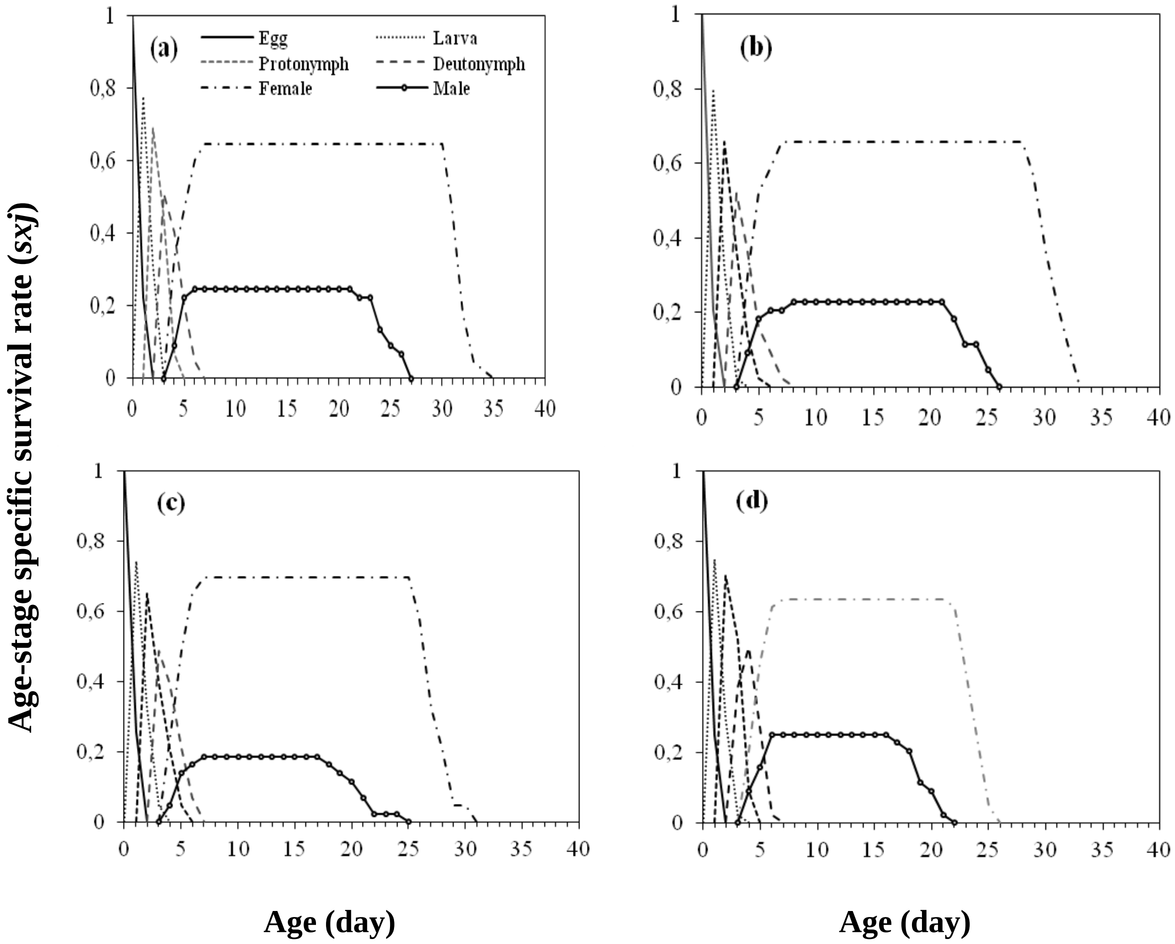

Figure 2 Age-stage-specific survival rate (s_{xj}) of *Neoseiulus californicus* for control and different concentrations of thiamethoxam: (a) Control, (b) LC_5, (c) LC_{10}, (d) LC_{20}.

Discussion

IPM program betterments need a comprehension of how pesticides/insecticides impress natural enemies of the pests that are being targeted. Insecticides may influence insects directly and/or via exposure to low-lethal concentrations (Guedes *et al*., 2016). Various studies have been conducted on the effects of various pesticides on biological parameters of two-spotted spider mite and predatory mites (Nadimi *et al*., 2009; Alinejad *et al*., 2015; Ganjisaffar and Perring, 2017; Havasi *et al*., 2018). However, no evidence is available with regard to low-lethal concentration (LC_5, LC_{10} and LC_{20}) of thiamethoxam on biological parameters of *N. californicus*. Determining the effects of pesticides on natural enemies can be useful in appropriate selection of these compounds for integrated pest management programs (Golmohammadi and Hejazi, 2014).

According to our results, thiamethoxam treatment had no significant effect on developmental time of different immature stages (egg, larvae, protonymph and deutonymph) of *N. californicus*, which is in accordance with Villanueva and Walgenbach (2005) who concluded that low-lethal doses of acetamiprid (115 ppm), thiamethoxam (37 ppm) and imidacloprid (60 ppm) had no significant effects on pre-adult duration of *N. fallacis* Garman. In our study, longevity and total lifespan were declined for both sexes of the *N. californicus* after treatment with two sublethal (LC_{10} and LC_{20}) concentrations of thiamethoxam (Table. 2), which is consistent with results provided by Döker *et al*. (2015) that showed a similar trend for immature survival and high mortality in *Iphiseius degenerans* Berlese (Acari: Phytoseiidae) after exposure to acetamiprid and thiamethoxam. Other studies have also confirmed the adverse effect of imidacloprid and/or thiamethoxam on *G. occidentalis* (Bostanian *et al*. 2009), *N. fallacis* (Bostanian *et al*., 2010) and *I. degenerans* (Döker *et al*., 2015), respectively.

It was especially noteworthy that the oviposition period and fecundity of *N. californicus* were affected by experimental treatments (LC_{10} and LC_{20}) which corroborates the results reported for another neonicotinoid insecticide, namely acetamiprid, which lowered drastically the fecundity of female *Galendromus occidentalis* (Nesbitt) by > 75% and *Amblyseius swirskii* Athias-Henriot (Beers and Schmidt, 2014; Fytrou *et al*., 2017). To the contrary, the fecundity of whitefly parasitoid *Encarsia inaron* (Walker) treated with low-lethal (62.5 and 23.37 ppm) concentration of imidacloprid, had a higher fecundity compared to a control treatment (Sohrabi *et al*., 2012).

In our opinion, this discrepancy between the results presumably occurred due to different examined concentrations of pesticide and the species differences in physiological responses to the insecticides.

Based on the obtained results, neither the pre-oviposition nor total pre-oviposition period showed significant variation. Our result was not in agreement with Xiao *et al*. (2016) who illustrated an increase trend for the pre-oviposition period of seven-spotted ladybird beetle, *Coccinella septempunctata* L., when treated by 0.484 and 4.837 mg l^{-1} of imidacloprid.

Life history parameters were affected by the low-lethal concentrations of thiamethoxam in some cases and in some others they were not, and that is why demographic search is an invaluable method of chemical toxicity against arthropods since such studies provide further understanding of the effect of the pesticide on insect (Stark and Banks, 2003).

In our study, the value obtained for gross reproductive rate (*GRR*) in the control treatment (27.18 offspring/individual), was similar to the value found by Khanamani *et al*. (2017) (27.69 offspring/individual) for *N. californicus*. There was a significant decrease in net reproduction rate (R_0), gross reproductive rate (*GRR*) and mean generation time (*T*) parameters in higher concentration (LC_{20}) of thiamethoxam. Our data is supported by those of Rahmani (2016) and Rahmani and Bandani (2013) who concluded that thiamethoxam treatment (LC_{30}), caused significant decrease inR_0 of important predator, *Macrolophus pygmaeus*Rambur (Hemiptera: Miridae) and aphid predator, *Hippodamia variegata* Goeze (Coleoptera: Coccinellidae).

No significant differences was reported for intrinsic rate of increase (*r*) and finite rate of increase (λ) of *N. californicus* exposed to different concentrations of thiamethoxam, which agrees with the findings of Zarandi *et al*. (2017) for *Iphiseiodes zuluagai* (Denmark and Muma) treated with imidacloprid and thiamethoxam.

The adult survival and age-specific fecundity curves demonstrated that sublethal concentrations of thiamethoxam caused reduction in survival and fecundity of offspring compared with the control. The reduced values for survival and fecundity have been reported in previous studies for *P. persimilis* and *N. fallacis,* when treated with thiamethoxam (Bostanian *et al*. 2010; Pozzebon *et al*. 2011). Similar to the results obtained by our work, in laboratory tests Stavrinides and Mills (2009) found that the survival rate of *Galendromus occidentalis* (Nesbitt) treated by imidacloprid (56.25mg/l of active ingredient), had a decreasing trend compared to control. These differences may be due to different predatory species.

In this work, the parameter of S_{xj} varied after treating individuals with thiamethoxam. For example, according to the curve of the age-stage specific survival rate (s_{xj}), increasing lethal concentrations led to an increase in

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

mortality. Thus, relative numbers alive (s_{xj}) were reduced by the LC_{10} followed by a considerable decrease in LC_{20} among both sexes male and female.

To conclude, it seems that the pesticides can be considered as an economic, labor-saving, and effective tool of pest management (Damalas and Eleftherohorinos, 2011) but IPM programs are complex and variable, and there is more work to be conducted to exactly understand these control strategies (Ullah, 2017). In general, the less of the pesticide may be used in combination with *N. californicus* in an IPM program of *T. urticae* (Roush, 1989, Dent, 2000).

Based on these results, we not only elucidated the low-lethal effects of thiamethoxam on the natural enemy *N. californicus*, but also contributed to better understanding of the interaction of this insecticide and *N. californicus*, and how natural enemies respond to environmental xenobiotic. Further behavioral and physiological studies are necessary to help identify in their field compatibility for two-spotted spider mite management and in order to develop biological pest control programs.

Acknowledgements

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

References

Alinejad, M., Kheradmand, K. and Fathipour, Y. 2014. Sublethal effects of fenazaquin on life table parameters of the predatory mite *Amblyseius swirskii* (Acari: Phytoseiidae). Experimental and Applied Acarology, 64 (3): 361-373.

Alinejad, M., Kheradmand, K. and Fathipour, Y. 2015. Sublethal effects of fenazaquin on biological performance of the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae): application of age-stage, two-sex life tables. Acarina, 23 (2): 172-180.

Alinejad, M., Kheradmand, K. and Fathipour, Y. 2016. Assessment of sublethal effects of spirodiclofen on biological performance of the predatory mite, *Amblyseius swirskii*. Systematic and Applied Acarology, 21 (3): 375-384.

Alzoubi, S. and Cobanoglu, S. 2007. Effects of sublethal dose of different pesticides on the two-spotted spider mite" *Tetranychus urticae* Koch" and its predatory mites under greenhouse conditions. World Journal of Agricultural Sciences, 3 (6): 764-770.

Aydemir, M. and Toros, S. 1990. Natural enemies of *Tetranychus urticae* Koch.(Acarina, Tetranychidae) on bean plants in Erzincan. Proceedings of the Second Turkish National Congress of Biological Control. Ege Universitesi, pp: 261-271.

Barbosa, P. A. 1998. Conservation Biological Control. Academic Press, Amsterdam.

Beers, E. H. and Schmidt, R. A. 2014. Impacts of orchard pesticides on *Galendromus occidentalis*: lethal and sublethal effects. Crop Protection, 56: 16-24.

Beers, E. H., Brunner, J. F., Dunley, J. E., Doerr, M. and Granger, K. 2005. Role of neonicotinyl insecticides in Washington apple integrated pest management. Part II. Nontarget effects on integrated mite control. Journal of Insect Science, 5 (1).

Biondi, A., Mommaerts, V., Smagghe, G., Viñuela, E., Zappalà, L. and Desneux, N. 2012. The non-target impact of spinosyns on beneficial arthropods. Pest Management Science, 68 (12): 1523-1536.

Bostanian, N. J., Hardman, J. M., Thistlewood, H. A. and Racette, G. 2010. Effects of six selected orchard insecticides on *Neoseiulus fallacis* (Acari: Phytoseiidae) in the laboratory. Pest Management Science, 66 (11): 1263-1267.

Bostanian, N. J., Thistlewood, H. A., Hardman, J. M., Laurin, M. C. and Racette, G. 2009. Effect of seven new orchard pesticides on *Galendromus occidentalis* in laboratory studies. Pest Management Science, 65 (6): 635-639.

Castagnoli, M. and Simoni, S. 1999. Effect of long-term feeding history on functional and numerical response of *Neoseiulus californicus*

(Acari: Phytoseiidae). Experimental and Applied Acarology, 23 (3): 217-234.

Chi, H. 1988. Life-table analysis incorporating both sexes and variable development rates among individuals. Environmental Entomology, 17 (1): 26-34.

Chi, H. 2016 TWO SEX-MSChart: A Computer Program for The Age-Stage, Two-Sex Life Table Analysis. National Chung Hsing University, Taichung, Taiwan.

Chi, H. S. I. N. and Liu, H. 1985. Two new methods for the study of insect population ecology. Bulletin of Institute of Zoology Academia Sinica, 24 (2): 225-240.

Çobanoğlu, S. and Alzoubi, S. 2008. Direct effects of some pesticides on two-spotted spider mite *Tetranychus urticae* Koch and its predatory mites (*Phytoseiulus persimilis* Athias-Henriot, *Neoseiulus californicus* [McGregor]) on cucumber plants under greenhouse conditions. 6th Symposium of the European Association of Acarologists, Montpellier.

Cranham, J. E. and Helle, W. 1985. Pesticide resistance in Tetranychidae. In: Helle, W. and Sabelis, M. W. (Eds.). Spider Mites: Their Biology, Natural Enemies, and Control. Elsevier, Amsterdam, pp: 405-421.

Croft, B. A. 1990. Arthropod biological control agents and pesticides. John Wiley and Sons Inc., New Jersey.

Damalas, C. A. and Eleftherohorinos, I. G. 2011. Pesticide exposure, safety issues, and risk assessment indicators. International Journal of Environmental Research and Public Health, 8 (5): 1402-1419.

Dent, D. 2000. Insect pest management. CABI Publishing, Wallingford.

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

Döker, İ, Pappas, M. L, Samaras, K, Triantafyllou, A, Kazak, C. and Broufas, G. D. 2015 Compatibility of reduced-risk insecticides with the non-target predatory mite *Iphiseius degenerans* (Acari: Phytoseiidae). Pest Management Science, 71 (9): 1267-1273.

Duso, C., Ahmad S., Tirello, P., Pozzebon, A., Klaric, V., Baldessari, M., Malagnini,V. and Angeli, G. 2014. The impact of insecticides applied in apple orchards on the predatory mite *Kampimodromus aberrans* (Acari: Phytoseiidae). Experimental and Applied Acarology, 62 (3): 391-414.

Elzen, G. W. 2001. Lethal and sublethal effects of insecticide residues on *Orius insidiosus* (Hemiptera: Anthocoridae) and *Geocoris punctipes* (Hemiptera: Lygaeidae). Journal of Economic Entomology, 94 (1): 55-59.

Fathipour, Y. and Maleknia, B. 2016. Mite predators. In: Ed, O. (Ed.). Ecofriendly pest management for food security. Elsevier, Amsterdam. pp: 329-366.

Forbes, V. E. and Calow, P. 1999. Is the per capita rate of increase a good measure of population-level effects in ecotoxicology?. Environmental Toxicology and Chemistry, 18 (7): 1544-1556.

Fytrou, N., Ilias, A., Sklivakis, J. and Tsagkarakou, A. 2017. Lethal and sublethal effects of selected insecticides on commercially available natural enemies of whiteflies. IOBC-WPRS Bulletin, 125: 19-27.

Galvan, T. L., Koch, R. L. and Hutchison, W. D. 2005. Effects of spinosad and indoxacarb on survival, development, and reproduction of the multicolored Asian lady beetle (Coleoptera: Coccinellidae). Biological Control, 34 (1): 108-114.

Ganjisaffar, F. and Perring, T. M. 2017. Effects of the miticide hexythiazox on biology of *Galendromus flumenis* (Acari: Phytoseiidae). International Journal of Acarology, 43 (2): 169-172.

Golmohammadi, G. and Hejazi, M. 2014. Toxicity and side effects of three insecticides on adult *Chrysoperla carnea* (Neu.: Chrysopidae) under laboratory conditions. Journal of Entomology Society of Iran, 33: 23-28.

Greathead, D. J. 1995.Benefits and risks of classical biological control. In: Hokkanen, H. M. T, Lynch, J. M. (Eds.). Biological control. Benefits and risks. Cambridge University Press, Cambridge, pp. 53-63.

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

Greco, N. M., Liljeström, G. G. and Sanchez, N. E. 1999. Spatial distribution and coincidence of *Neoseiulus californicus* and *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae) on strawberry. Experimental and Applied Acarology, 23 (7): 567-579.

Greco, N. M., Sánchez, N. E. and Liljesthröm, G. G. 2005. *Neoseiulus californicus* (Acari: Phytoseiidae) as a potential control agent of *Tetranychus urticae* (Acari: Tetranychidae): effect of pest/predator ratio on pest abundance on strawberry. Experimental and Applied Acarology, 37 (1): 57-66.

Guedes, R. N. C., Smagghe, G., Stark, J. D. and Desneux, N. 2016. Pesticide-induced stress in arthropod pests for optimized integrated pest management programs. Annual review of entomology, 61: 43-62.

Hamedi, N., Fathipour, Y. and Saber, M. 2010. Sublethal effects of fenpyroximate on life table parameters of the predatory mite *Phytoseius plumifer*. Biocontrol, 55 (2): 271-278.

Hamedi, N., Fathipour, Y., Saber, M. and Garjan, A. S. 2009. Sublethal effects of two common acaricides on the consumption of *Tetranychus urticae* (Prostigmata: Tetranychidae) by *Phytoseius plumifer* (Mesostigmata: Phytoseiidae). Systematic and Applied Acarology, 14 (3): 197-205.

Hassan, S. A. and van de Veire. 2004. Compatibility of pesticides with biological control agents. In: Heinz, K. M., van Driesche, R. G. and Parrella, M. P. (Eds), Biocontrol in Protected Crops. Ball Publishing, Batavia, pp: 129-147.

Havasi, M., Kheradmand, K., Mosallanejad, H. and Fathipour, Y. 2018. Sublethal effects of diflovidazin on life table parameters of two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae). International Journal of Acarology, 4 (2-3): 115-120.

Helle, W. and Overmeer, W. P. J. 1985. Toxicological test methods. In: Helle, W. and Sabelis, M. W. (Eds), Spider Mites. Their Biology, Natural Enemies and Control. Vol. 1A. Elsevier, Amsterdam, Oxford, New York, pp: 391-395.

Helle, W. and Sabelis, M. W. 1985. Spider Mites: Their Biology, Natural Enemies and Control. Elsevier, Amsterdam.

Huffaker, C. B, Van De Vrie, M. and McMurtry, J. A. 1969. The ecology of tetranychid mites and their natural control. Annual Review of Entomology, 14 (1): 125-174.

Isman, M. B. 2000. Plant essential oils for pest and disease management. Crop protection, 19 (8): 603-608.

Kaplan, P., Yorulmaz, S. and Ay, R. 2012. Toxicity of insecticides and acaricides to the predatory mite *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae). International Journal of Acarology, 38 (8): 699-705.

Khanamani, M., Fathipour, Y. and Hajiqanbar, H. 2013. Population growth response of *Tetranychus urticae* to eggplant quality: application of female age-specific and age-stage, two-sex life tables. International Journal of Acarology, 39 (8): 638-648.

Khanamani, M., Fathipour, Y.,Talebi, A. A. and Mehrabadi, M. 2017. How pollen supplementary diet affect life table and predation capacity of *Neoseiulus californicus* on two-spotted spider mite. Systematic and Applied Acarology, 22 (1): 135-147.

Khanamani, M., Fathipour, Y., Talebi, A. A. and Mehrabadi, M. 2017. Linking pollen quality and performance of *Neoseiulus californicus* (Acari: Phytoseiidae) in two-spotted spider mite management programmes. Pest management science, 73 (2): 452-461.

Kim, M., Shin, D., Suh, E. and Cho, K. 2004. An assessment of the chronic toxicity of fenpyroximate and pyridaben to *Tetranychus urticae* using a demographic bioassay. Applied Entomology and Zoology, 39 (3): 401-409.

Lewis, W. J., Van Lenteren, J. C., Phatak, S. C. and Tumlinson, J. H. 1997. A total system approach to sustainable pest management. Proceedings of the National Academy of Sciences, 94 (23): 12243-12248.

Lima, D. B., Monteiro, V. B., Guedes, R. N. C., Siqueira, H. A. A., Pallini, A. and Gondim, M. G. C. 2013. Acaricide toxicity and synergism of fenpyroximate to the coconut mite predator *Neoseiulus baraki*. Biocontrol, 58 (5): 595-605.

Maienfisch, P., Huerlimann, H., Rindlisbacher, A., Gsell, L., Dettwiler, H., Haettenschwiler, J., Sieger E. and Walti., M. 2001. The discovery of thiamethoxam: a second-generation neonicotinoid. Pest Management Science, 57 (2): 165-176.

Maleknia, B., Fathipour, Y. and Soufbaf, M. 2016. How greenhouse cucumber cultivars affect population growth and two-sex life table parameters of *Tetranychus urticae* (Acari: Tetranychidae). International Journal of Acarology, 42 (2): 70-78.

McMurtry, J. A. and Scriven, G. T. 1965. Insectary production of phytoseiid mites. Journal of Economic Entomology, 58 (2): 282-284.

McMurtry, J. A., De Moraes., G. J. and Sourassou, N. F. 2013. Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. Systematic and Applied Acarology, 18 (4): 297-321.

Nachman, G. and Zemek, R. 2003. Interactions in a tritrophic acarine predator-prey metapopulation system V: Within-plant dynamics of *Phytoseiulus persimilis* and *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae). Experimental and Applied Acarology, 29 (1-2): 35-68.

Nadimi, A., Kamali, K., Arbabi, M. and Abdoli, F. 2009. Selectivity of three miticides to spider mite predator, *Phytoseius plumifer* (Acari: Phytoseiidae) under laboratory conditions. Agricultural Sciences in China, 8: 326-331.

Naher, N., Islam, W. and Haque, M. M. 2005. Predation of three predators on two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). Journal of Life Earth Science, 1: 1-4.

Nauen, R., Ebbinghaus-Kintscher, U., Salgado, V. L. and Kaussmann, M. 2003. Thiamethoxam is a neonicotinoid precursor converted to clothianidin in insects and plants. Pesticide Biochemistry and Physiology, 76 (2): 55-69.

Nauen, R., Stumpf, N., Elbert, A., Zebitz, C. P. W. and Kraus, W. 2001. Acaricide toxicity and resistance in larvae of different strains of *Tetranychus urticae* and *Panonychus ulmi* (Acari: Tetranychidae). Pest Management Science, 57 (3): 253-261.

Newsom, L. D., Smith, R. F. and Whitcomb, W. H. 1976. Selective pesticides and selective use of pesticides. In: Huffaker, C. and Messenger, P. (Eds.). Theory and practice of biological control. Academic Press, New York, pp: 565-591.

Poletti, M., Hollandia Nunes Maia, A. D. and Omoto, C. 2007. Toxicity of neonicotinoid insecticides to *Neoseiulus californicus* and *Phytoseiulus macropilis* (Acari: Phytoseiidae) and their impact on functional response to *Tetranychus urticae* (Acari: Tetranychidae). Biological Control, 40: 30-36.

Pozzebon, A., Duso, C., Tirello, P. and Ortiz, P. B. 2011. Toxicity of thiamethoxam to *Tetranychus urticae* Koch and *Phytoseiulus persimilis* Athias-Henriot (Acari Tetranychidae, Phytoseiidae) through different routes of exposure. Pest Management Science, 67 (3): 352-359.

Rahmani, S. 2016. LC30 effects of thiamethoxam and pirimicarb, on population parameters and biological characteristics of *Macrolophus pygmaeus* (Hemiptera: Miridae). Arthropods, 5 (2): 44.

Rahmani, S. and Bandani, A. R. 2013. Sublethal concentrations of thiamethoxam adversely affect life table parameters of the aphid predator, *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae). Crop Protection, 54: 168-175.

Raupp, M. J., Webb, R. E., Szczepaniec, A., Booth, D. and Ahern, R. 2004. Incidence, abundance, and severity of mites on hemlocks following applications of imidacloprid. Journal of Arboriculture, 30 (2): 108-113.

Riahi, E., Fathipour, Y., Talebi, A. A. and Mehrabadi, M. 2017. Attempt to Develop Cost-Effective Rearing of *Amblyseius swirskii* (Acari: Phytoseiidae): Assessment of Different Artificial Diets. Journal of Economic Entomology, 110 (4): 1525-1532.

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

Roubos, C. R., Rodriguez-Saona, C. and Isaacs, R. 2014. Mitigating the effects of insecticides on arthropod biological control at field and landscape scales. Biological control, *75*: 28-38.

Roubos, C. R., Rodriguez-Saona, C., Holdcraft, R., Mason, K. S. and Isaacs, R. 2014. Relative toxicity and residual activity of insecticides used in blueberry pest management: mortality of natural enemies. Journal of Economic Entomology, 107 (1): 277-285.

Roush, R. T. 1989. Designing resistance management programs: how can you choose? Pesticide Science, 26: 423-441.

SAS, Institute. 2002. SAS software version 9.0. SAS Institute, Cary.

Sedaratian, A., Fathipour, Y. and Moharramipour, S. 2011. Comparative life table analysis of *Tetranychus urticae* (Acari: Tetranychidae) on 14 soybean genotypes. Insect Science, 18 (5): 541-553.

Sharma, D. R. and Lal, O. P. 2002. Bio-efficacy of thiamethoxam in comprison to recommended insecticides against leafhopper and white fly of brinjal (*Solanum melongena* L.). Journal of Entomological Research, 26 (3): 257-262.

Sohrabi, F., Shishehbor, P., Saber, M. and Mosaddegh, M. S. 2012. Lethal and sublethal effects of buprofezin and imidacloprid on the whitefly parasitoid *Encarsia inaron* (Hymenoptera: Aphelinidae). Crop Protection, 32: 83-89.

Stark, J. D. and Banks, J. E. 2003. Population-level effects of pesticides and other toxicants on arthropods. Annual Review of Entomology, 48 (1): 505-519.

Stavrinides, M. C. and Mills, N. J. 2009. Demographic effects of pesticides on biological control of Pacific spider mite (*Tetranychus pacificus*) by the western predatory mite (*Galendromus occidentalis*). Biological Control, 48 (3): 267-273.

Statistic, IS. 2011. IBM SPSS STATISTIC program, version 19 statistical software packages. IBM Corporation, New York.

Swirski, E., Amitai, S. and Dorzia, N. 1970. Laboratory studies on the feeding habits, post embryonic survival and oviposition of the predaceous mites *Amblyseius chilenensis* Dosse and *Amblyseius hibisci* Chant [Acarina: Phytoseiidae] on various kinds of food substances. Entomophaga, 15: 93-106. http://dx.doi.org/10.1007/BF02371627.

Szczepaniec, A., Creary, S. F., Laskowski, K. L., Nyrop, J. P. and Raupp, M. J. 2011. Neonicotinoid insecticide imidacloprid causes outbreaks of spider mites on elm trees in urban landscapes. PLoS One, 6 (5): p.e20018.

Torres, J. B., Silva-Torres, C. S., and Barros, R. 2003. Relative effects of the insecticide thiamethoxam on the predator *Podisus nigrispinus* and the tobacco whitefly *Bemisia tabaci* in nectaried and nectariless cotton. Pest Management Science: formerly Pesticide Science. 59 (3): 315-23.

Ullah, M. S. and Lim, U. T. 2017. Synergism of *Beauveria bassiana* and *Phytoseiulus persimilis* in control of *Tetranychus urticae* on bean plants. Systematic and Applied Acarology, 22 (11): 1924-1935.

Villanueva, R. T. and Walgenbach, J. F. 2005. Development, oviposition, and mortality of *Neoseiulus fallacis* (Acari: Phytoseiidae) in response to reduced-risk insecticides. Journal of Economic Entomology, 98 (6): 2114-2120.

Watson, T. F. 1964. Influence of host plant condition on population increase of *Tetranychus telarius* (Linnaeus) (Acarina: Tetranychidae). Hilgardia, 35: 273-322.

Xiao, D., Zhao, J., Guo, X., Chen, H., Qu, M., Zhai, W., Desneux, N., Biondi, A., Zhang, F. and Wang, S. 2016. Sublethal effects of imidacloprid on the predatory seven-spot ladybird beetle *Coccinella septempunctata*. Ecotoxicology, 25 (10): 1782-1793.

Zanardi, O. Z., Bordini, G. P., Franco, A. A., Jacob, C. R. and Yamamoto, P. T. 2017. Sublethal effects of pyrethroid and neonicotinoid insecticides on *Iphiseiodes zuluagai* Denmark and Muma (Mesostigmata: Phytoseiidae). Ecotoxicology, 26 (9): 1188-98.

Zhao, S. H. 2000. Plant Chemical Protection. China Agriculture Press, Beijing, China. (in Chinese).

[DOR: 20.1001.1.22519041.2020.9.1.9.6]

تأثیر غلظت‌های کم‌کشنده تیامتوکسام بر پارامترهای بیولوژیکی
Neoseiulus californicus (Acari: Phytoseiidae)

محمدرضا هواسی[۱]، کتایون خردمند[۱*]، هادی مصلی‌نژاد[۲] و یعقوب فتحی‌پور[۳]

۱- گروه حشره‌شناسی و بیماری‌های گیاهی، پردیس ابوریحان، دانشگاه تهران، تهران، ایران.
۲- مؤسسه تحقیقات حفاظت گیاهان ایران، سازمان آموزش و ترویج تحقیقات کشاورزی (AREEO)، تهران، ایران.
۳- گروه حشره‌شناسی کشاورزی، دانشکده کشاورزی، دانشگاه تربیت مدرس، تهران، ایران.
پست الکترونیکی نویسندگان مسئول مکاتبه: kkheradmand@ut.ac.ir

دریافت: ۹ اردیبهشت ۱۳۹۸؛ پذیرش: ۲۱ مهر ۱۳۹۸

چکیده: به‌منظور اجرای موفقیت آمیز برنامه‌های مدیریت تلفیقی آفات (IPM)، آگاهی در مورد اثرات کشنده و کم‌کشنده سموم بر دشمنان طبیعی امری ضروری می‌باشد. پژوهش حاضر به بررسی اثر زیرکشنده تیامتوکسام بر پارامترهای جدول زندگی نسل بعدی کنه شکارگر *Neoseiulus californiaicus* McGregor (Acari: Phytoseiidae) تغذیه شده از کنه تارتن دولکه‌ای *Tetranychus urticae* Koch در شرایط آزمایشگاهی پرداخته است. غلظت‌های زیرکشنده LC_{5}، LC_{10} و LC_{20} براساس روش دز اثر تعیین شد. داده‌های خام به‌دست آمده براساس جدول زندگی دوجنسی سن-مرحله زیستی، تجزیه و تحلیل شد. قرار گرفتن در معرض غلظت‌های زیرکشنده تیامتوکسام تأثیر معنی‌داری بر زمان مراحل رشدی کنه‌های تیمار شده نداشت. در مقایسه با تیمار شاهد، دوره تخم‌ریزی کنه‌های تیمار شده با غلظت‌های LC_{5}، LC_{10} و LC_{20} به‌طور قابل‌توجهی کاهش یافت. بیش‌ترین و کم‌ترین مقدار باروری کل به‌ترتیب در غلظت شاهد (۳۵/۳ تخم/ماده/روز) و غلظت LC_{20} (۲۳/۶ تخم/ماده/روز) به‌دست آمد. نرخ تولیدمثل خالص (R_0) با افزایش دز از LC_{5} (۲۲/۶ نتاج) به LC_{20} (۱۵/۰ نتاج) کاهش یافت. نرخ ذاتی افزایش جمعیت (r) و نرخ متناهی افزایش جمعیت (λ)، با افزایش غلظت تحت تأثیر قرار نگرفت. متوسط طول زندگی یک نسل (T) در غلظت بالای LC_{20} (۱۳/۲روز) در مقایسه با تیمار شاهد (۱۴/۷روز) کاهش معنی‌داری داشت. در نتیجه، تأثیرات غلظت زیرکشنده تیامتوکسام در ترکیب با شکارگر *N. california* به‌منظور طراحی برنامه‌های مدیریت کنه تارتن دولکه‌ای مورد بحث قرار گرفته است.

واژگان کلیدی: کنه شکارگر، LC_{50}، *Tetranychus urticae*، سمّیت، جدول زندگی

[DOR: 20.1001.1.22519041.2020.9.1.9.6]