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Article

Sublethal effects of two acaricides, propargite and fenpyroximate on life history of *Macrolophus pygmaeus* (Hemiptera: Miridae) reared on the two-spotted spider mite eggs

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ABSTRACT

Macrolophus pygmaeus (Rambur) is a generalist predator that naturally colonizes and commercially is used as a biological control agent of various arthropod pests of agricultural crops. Since pesticides compatibility with natural enemies is a main concern for IPM programs, the aim of the current study was to assess the lethal and sublethal side effects of two acaricides, propargite and fenpyroximate widely used to control phytophagous mites. In bioassay experiments, *M. pygmaeus* adult individuals were fed on the two-spotted spider mite eggs immersed in the different concentrations of both chemicals during 24 hours. Probit analysis represented that LC_{50} values of propargite and fenpyroximate were 3.41 and 5.74 mg (ai) L^{-1}, respectively. Demographic analysis performed with LC_{30} of each acaricides using the age-stage, two-sex life table procedure. Results showed that both chemicals had significant effects on the developmental time of all stages, the total pre-oviposition period (TPOP), the adult pre-oviposition period (APOP) and females' fecundity. Also, all main population statistics were affected by the sublethal concentrations. The intrinsic rate of increase (r) was 0.15 day^{-1} in the control. However, this parameter in propargite and fenpyroximate treatments declined to 0.057 and 0.083 day^{-1}, respectively. The net reproductive rate (R_0) in control, propargite and fenpyroximate treated insects was 99.96, 21.16, and 71.5 offspring/individual, respectively. Mean generation time (T) in control showed 30.08 days, whilst it was 53.17, and 51.02 days in propargite and fenpyroximate sublethal treated insects, respectively. Consequently, the results achieved in this study showed that both acaricides have potential to affect the predator, adversely. Thus, they are not suitable for IPM programs in agricultural systems where this mirid bug exists as a capable biocontrol agent.

KEY WORDS: Bioassay; bug; IPM; life table; *Tetranychus urticae*.

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INTRODUCTION

Two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), one of the most critical pests in agricultural areas, can damage more than 1100 plant species belonging to about 150 field crops, fruits, vegetables, and ornamental plants all around the world (Golec *et al.* 2020). The most common management method against this highly polyphagous pest is chemical control. Thus, there

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are a wide variety of acaricides with different modes of action for control of *T. urticae* (Adesanya *et al*. 2019; Alpkent *et al.* 2020). On the other hand, *T. urticae* has high potential in developing resistance to many chemicals because this arthropod can produce many generations per year, and complete its development time very fast, especially when the living conditions are constant (i.e. greenhouse conditions). In fact, *T. urticae* has developed resistance to nearly all the acaricides available for its control and ranked the fifth out of the 512 cases developed resistance to the pesticides (Adesanya *et al.* 2019; Solmaz *et al.* 2020). In addition to the resistance, pesticides application could contaminate environment, and reduce populations of natural enemies cause pest recoveries or even secondary pest outbreaks (Rahmani and Bandani 2013).

Generally, insect and mite pests are attacked by various pathogens and arthropod natural enemies (predators and parasitoids) which suppress their populations. *Tetranychus urticae* is attacked by many natural enemies, some of them such as *Neoseiulus californicus* (McGregor) (Song *et al*. 2016; Ajila *et al.* 2019), *Amblyseius swirskii* Athias-Henriot (Mortazavi *et al.* 2019), *Amblyseius chiapensis* De Leon (Amaral *et al*. 2020), *Phytoseiulus persimilis* Athias-Henriot (Shaef Ullah and Lim 2017), *Stethorus punctillum* Weise (Rott and Ponsonby 2000; Shah and Appleby 2019), *Chrysoperla carnea* (Stephens) (Hassanpour *et al*. 2009; Mena *et al.* 2020), *Orius minutus* (Linnaeus) (Rahman *et al.* 2020), *Orius albidipennis* (Reuter) (El Arnaouty *et al.* 2018), *Macrolophus pygmaeus* (Rambur) (Zhang *et al*., 2018), etc. are noticed as the biological control agents. In Integrated Pest Management (IPM) programs the combination of chemical and biological controls is a common practice and applying selective and compatible pesticides with biological control agents is indeed the exact concept of IPM (Giles *et al*. 2017). The presence of natural enemies, is a crucial issue for a successful IPM program (De Armas *et al.* 2020). Moreover, during the IPM procedures, predators and parasitoids should keep sufficient efficiency for suppression of the pests in the fields and greenhouses.

Pesticides, along with death, may have sublethal effects on non-target organisms and can adversely affect their ecological and biological parameters through changing fertility, fecundity, developmental rate, longevity, egg hatchability, morphological deformation, foraging behavior, predation rate, and life table parameters (Stanley and Preetha 2016; Pérez-Aguilar *et al*. 2018; Castilhos *et al*. 2018; Passos *et al.* 2018; Iftikhar *et al.* 2020; Soares *et al*. 2020). Therefore, it is necessary to calculate lethal and sublethal effects of a pesticide on natural enemies along with the pests to take a better and clearer picture about effect of the chemicals on the biological components of the system. So, it can help us to introduce more selective pesticides in an IPM program (Stanley and Preetha 2016).

In agricultural systems, generalist predators are more advantageous than specialists, because they have the ability to exist on different food sources or exactly they have wide variety of hosts. Thus, the generalist predators can continue to live in the agroecosystem without target pests and prevent the resurgence of the main pests (De Armas *et al*. 2020). The predatory bugs of the family Miridae can attack a wide range of prey species, such as aphids, thrips, whiteflies, and lepidopteran pests. Also, as true omnivorous predators, they feed on both plant and prey, so they can even be alive in somewhere prey does not exist (Leman *et al*. 2020). *Macrolophus pygmaeus* (Rambur), as well as completing its development during the time feeding on plant sap or pollen, was reported as predator of several insects including *Trialeurodes vaporariorum* (Westwood), *Myzus persicae* (Sulzer), *Macrosiphum euphorbiae* (Thomas), *Aphis gossypii* Glover (Perdikis and Lykouressis 2000, 2002), *Macrosiphum euphorbiae* (Thomas) (Lykouressis *et al*. 2007), *Tuta absoluta* (Meyrick) (Urbaneja *et al*. 2009; Passos *et al*. 2018), and *Echinothrips americanus* Morgan (Leman *et al*. 2020). This polyphagous mirid could also preyed on *T. urticae* (Gigon *et al*. 2016). Because this predator may contact with pesticides used against different pests in agricultural systems, a number of studies evaluated pesticides effects on survival and biology of *M. pygmaeus* (Arnó and Gabarra 2011; Martinou *et al*. 2014; Martinou and Stavrinides 2015; Rahmani *et al*. 2016; Sharifian *et al.* 2017; Ricupero *et al*. 2020).

SUBLETHAL EFFECTS OF TWO ACARICIDES ON LIFE HISTORY OF *M. PYGMAEUS*

In this study, potential risks of two acaricides, propargite and fenpyroximate were examined on life table parameters and some biological characteristics of the mirid predator. Both chemicals are vastly used against *T. urticae* alone or mixture with other chemicals (Motoba *et al*. 1992; Wilson *et al*. 1995; Herron *et al*. 2003; Liang *et al*. 2018). Fenpyroximate (tert-butyl (E)-α-(1,3-dimethyl-Sphenoxypyrazol-4-ylmethyleneamino-oxy)-p toluate) is a chemical with knockdown activities and acaricidal effect on phytophagous mites belonging to Tetranychidae family due to inhibition of NADH: ubiquinone oxidoreductase (complex I), the mitochondrial respiratory-chain enzyme (Shiraishi *et al.* 2012). According to Insecticide Resistance Action Committee (IRAC), this chemical belongs to the group of mitochondrial complex I electron transport inhibitors (21) and chemical classification of METI acaricides and insecticides (21A). As a selective pesticide, fenpyroximate does not have any clear toxic effect on the other arthropods such as insects, and soil-living mites (Motoba *et al*. 1992; Kim *et al*. 2004). Another selective chemical is propargite (2-(4-(tert-Butyl)phenoxy) cyclohexyl prop-2-yn-1-yl sulfite) which is suitable for control of a variety of phytophagous mites active on fruit trees, vegetables, cotton, nuts, hops, vines, and many other crops. This organosulfur acaricide can inhibit magnesium-stimulated ATPase (Sherwani and Mukhtar 2019). Based on IRAC classification, propargite has its place in the group of inhibitors of mitochondrial ATP synthase (12) and chemical class of propargite (12C). There are several studies show adverse effects of propargite (Lira *et al*. 2015; Asadi *et al*. 2018; Alinejad *et al*. 2020) and fenpyroximate (Hamedi *et al*. 2010; Park *et al*. 2011; Lopez *et al*. 2015; Ghasemzadeh and Qureshi 2018) in sublethal concentrations against biological control agents including predators and parasitoids.

Since there is no study about the effects of propargite and fenpyroximate on *M. pygmaeus*, in the current study, the female and male adult bugs were fed with *T. urticae* eggs contaminated with sublethal concentrations of the both acaricides to take a better picture about effects of these chemicals on the next generation. Thus, the fecundity, longevity, growth, and developmental duration of the predator population could be measured and the demographic parameters were evaluated using age stage, two-sex life table method. Also, compatibility of these acaricides for effective management of two-spotted spider mite in perspective of IPM was described.

MATERIAL AND METHODS

Plant, Prey, and predator cultures

Plants used in the current experiments were 4 weeks-old common bean, *Phaseolus vulgaris* L. (cv. Humilis) grown in a controlled room at 25 ± 2 °C, 65 ± 5% relative humidity (RH), and a photoperiod 16:8 hours (L: D). *Tetranychus urticae* population was collected from infested common bean leaves in acarology laboratory at Department of Plant Protection, College of Agriculture, University of Tehran, Karaj, Iran. *Macrolophus pygmaeus* was collected from tomato fields in Hashtgerd, Alborz province of Iran. The predator was reared in the separate Petri dishes (15 cm diameters) for four generations fed with *T. urticae* eggs on the common bean leaves in a growth chamber (25 ± 2 °C, 65 ± 5% RH, and a photoperiod 16:8 hours (L: D)).

Chemicals

The commercial formulation of two acaricides, propargite (Omite®, EC 57%, Mahan, Iran) and fenpyroximate (Ortus®, SC 5%, Giah, Iran) were used in this study. Toxicity of both chemicals was assessed on adult individuals of *M. pygmaeus*. Also, the sublethal concentrations of each acaricide were assessed on survival and life table parameters of the predator during a generation.

Bioassay

Bioassay experiments were accomplished regarding to the method described by Bastos *et al*. (2006) with some modifications for the predator. In this method, 24-h eggs of the two-spotted spider mites, dipping in different concentrations of the acaricides were introduced to *M. pygmaeus* adult individuals. The experimental units were bean leaf discs which were placed on moist cotton (abaxial surface up) in Petri dishes with 8 cm diameter covered with lids that had a 2-cm diameter screened hole for ventilation (Golec *et al*. 2020). Primarily, 20 mated female adult mites at similar developmental status were put on surface of the leaf discs and let them to lay eggs. After 24 hours, the adults were removed using a camel hair brush. The leaf discs were dipped into the different concentrations of propargite (0.35, 0.78, 1.66, 3.55, 7.68 mg (ai) L^{-1}) and fenpyroximate (0.69, 1.41, 2.90, 5.90, 12.07 mg (ai) L^{-1}) caused the mirid bugs mortality between 20 to 80%, according to the pretests done similar to the principal assays. The dipping duration lasted for 10 seconds for every disc to make sure that the mite eggs were fully soaked in all solutions. After drying, the leaves were introduced to *M. pygmaeus* in the experimental units under the bug rearing constant conditions (25 ± 2 °C, 65 ± 5% RH, and a photoperiod 16:8 hours (L: D)). The distilled water only was used as a control and each treatment was performed on three replicates. 20 individuals were used for each concentration. However, the number of the mirid bugs in control was fewer. Therefore, the experiment was done with total number of 340 adult individuals of both sexes at the same age (24 hours). Every bug did not move after 24 hours, was considered as a dead individual.

Study side effects of propargite and fenpyroximate on biological statistic of M. pygmaeus

Twenty adult individuals of *M. pygmaeus* (males and females) which were almost at the same age were collected from the colony. Every male and female were put on an area similar to bioassay unit where the leaf bean containing *T. urticae* eggs treated with LC_{30} of each chemical.

Macrolophus pygmaeus lays its eggs into the stems of bean leaves and a precise look was necessary to find the horn of the eggs protruding from stems putting on the surfaces of the leaves. Females and males were kept together during seven days, the presumed pre-oviposition period and their units were changed every day by the other fresh bean leaves containing the mites' eggs and treated by desirable chemical concentrations. After seven days, the experimental units were checked every 24 hours and newly emerged nymphs (approximately 100 individuals for every treatment) were transferred to the new Petri dishes and supplied daily with untreated *T. urticae* eggs as food. The experiments including two treatments and one control was performed in a growth chamber at conditions 25 ± 2 °C, 65 ± 5% RH, and a photoperiod 16:8 hours (L: D). Each individual was considered as one replicate. The experimental units were surveyed every day and development besides mortality were checked (Chi and Yang 2003; Rahmani and Bandani 2013). After the adults' emergence, both sexes were paired to record their survival and the number of eggs laid, every 24 hours. The experiment continued until the death of all the individuals (Rahmani *et al*. 2016).

Data analysis

In the bioassay experiment, concentration-mortality regression was evaluated for the eggs using probit analysis (Polo-PC Probit and Logit analysis; LeOra Software, 1997) in order to determine the lethal concentrations (LC values) and slopes in 95% Fiducial Limit (FL).

Data on survival, developmental time of all individuals of *M. pygmaeus*, in addition to the female daily fecundity and pre-oviposition period were analyzed according to the age-stage, two-sex life table theory (Chi and Liu 1985; Chi 1988) using the program TWOSEX-MSChart described by Chi (2019).

The intrinsic rate of increase (*r*) as the most important demographic statistic, was evaluated using Euler-Lotka equation with age indexed from 0 (Goodman 1982):

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

Also, the rest of the life table parameters presented below were calculated for each cohort:

Net reproductive rate (R_0)

$$(2)\quad R_0 = \sum_{x=0}^{\infty} l_x\, m_x$$

Mean generation time (T)

$$(3)\quad T = \ln \frac{R_0}{r}$$

And finite rate of increase

$$(4)\quad \lambda = e^r$$

Moreover, age-specific survival rate (lx) is the chance of a newly laid egg to exist at age x, age-specific fecundity (mx) is explained as the mean fecundity of individuals at age x, age-stage fecundity (fxj) is the mean fecundity of females at age x, the age-stage survival rate (sxj) means the probability that a newly laid egg will exist to age x and stage j), the age-stage reproductive value (vxj) is known as the involvement of individuals of age x and stage j to the future population, and age-stage life expectancy (exj) means the length of the time that an individual of x and j is predicted to live (Chi and Liu 1985; Chi and Su 2006; Yang *et al*. 2015).

The means and standard errors of data were determined using 100,000 bootstrap replicates. The treatments were compared using the paired bootstrap test were determined in TWOSEX-MS Chart based on the confidence interval of the difference between treatments (Chi 2019). All demographic value curves were constructed using SigmaPlot 11.0.

RESULTS

Values of LC_{50} for the mirid bug adult individuals affected by propargite and fenpyroximate were 3.41 (2.08–3.97) and 5.74 (3.28–6.46) mg (ai) L^{-1}, respectively, according to the concentration-response bioassay (Table 1). Also, the concentrations (as well the 95% confidence intervals) showed 30% mortality, were 0.756 (0.598–1.08) and 1.25 (0.91–2.18) mg (ai) L^{-1} when propargite and fenpyroximate were used, respectively (Table 1).

Table 1. Toxicity of propargite and fenpyroximate on the generalist predator, *Macrolophus pygmaeus* through ingestion of the contaminated eggs of *Tetranychus urticae*.

Acaricides	N[a]	Concentration mg (ai) litre $^{-1}$ (95% CL)$^{-1}$		Slope ± SE	X^2 (df)
		LC_{30}	LC_{50}		
Propargite	340	0.756 (0.598–1.08)	3.41 (2.08–3.97)	3.89±0.03	9.2 (13)
Fenpyroximate	340	1.25 (0.91–2.18)	5.74 (3.28–6.46)	7.16±0.01	11.31 (13)

X^2 is significant ($p < 0.05$).
[a] Number of subjects.

Both propargite and fenpyroximate had significant effect on the developmental period of the eggs, nymphs, females, and fecundity of *M. pygmaeus* ($P < 0.0001$) (Table 2). However, propargite did not show any significant effect on the developmental time of the male individuals when compared to the control (Table 2). Adult pre-oviposition period (APOP) and total pre-oviposition period (TPOP) increased significantly with sublethal concentrations of propargite and fenpyroximate, but there was not any significant difference between APOPs of the two chemical treatments (Table 2). Adults in the control produced 217.3 nymphs per female, although the fecundity in the bugs affected by fenpyroximate and propargite showed about 1.7 and 4.7 times reduction, respectively (Table 2).

Table 2. Life history parameters (mean ± SE) of *Macrolophus pygmaeus* after feeding the two spotted-spider mite eggs treated with sublethal concentrations (LC_{30}) of propargite and fenpyroximate.

Acaricides	Egg Develop. time (days)	Nymph Develop. time (days)	Female Develop. time (days)	Male develop. time (days)	APOP[a] (days)	TPOP[b] (days)	Fecundity (Nymphs/ Females)
Propargite	16.78 ± 0.33^{a}	31.72 ± 0.59^{a}	14.49 ± 0.18^{b}	10.81 ± 0.71^{b}	0.63 ± 0.07^{a}	48.67 ±0.85 ^{a}	46.0 ± 1.24^{c}
Fenpyroximate	15.9 ± 0.54^{b}	25.83 ± 0.24^{b}	18.65 ± 0.24^{a}	14.35 ± 0.54^{a}	0.69 ± 0.06^{a}	46.73 ± 0.82 ^{b}	130.8 ± 3.32^{b}
Control	9.35 ± 0.24^{c}	16.55 ± 0.49^{c}	14.01 ± 0.3 ^{c}	10.91 ± 0.12^{b}	0.24 ± 0.063^{b}	25.74 ± 0.85 ^{c}	217.3 ± 10.02^{a}

Means in a column followed by different letters are significantly different ($P < 0.0001$).
[a] Adult Pre-Oviposition Period
[b] Total Pre-Oviposition Period

All population parameters of *M. pygmaeus* were changed due to the long-term effects of both acaricides (Table 3). The intrinsic rate of increase, finite rate of increase, and net reproductive rate in the control illustrated the highest values followed by fenpyroximate and propargite, respectively ($P < 0.0001$) (Table 3). In fact, the intrinsic rate of increase (r) in control, fenpyroximate, and propargite was 0.150, 0.083, and 0.057 day^{-1}, respectively. Alongside the r, the finite rate of increase (λ) performed 1.165, 1.087, and 1.059 day^{-1} in control, fenpyroximate, and propargite, respectively. Net reproductive rate (R_0) was 99.96 offspring/individual in control, although it was evaluated 71.5, and 21.16 in fenpyroximate, and propargite, respectively (Table 3). On the other hand, the mean generation time (T) in the control was 30.08 day, though this statistic increased in fenpyroximate (51.02), and propargite (53.17), respectively (Table 3).

Table 3. Effects of propargite and fenpyroximate on population statistics (Mean ± SE) of *Macrolophus pygmaeus* after feeding the two spotted-spider mite eggs treated with sublethal concentrations (LC_{30}) of propargite and fenpyroximate.

Demographic parameters	Propargite	Fenpyroximate	Control
r **(day^{-1})**	0.057 ± 0.002^{c}	0.083 ± 0.002^{b}	0.150 ± 0.004^{a}
λ **(day^{-1})**	1.059 ± 0.002^{c}	1.087 ± 0.002^{b}	1.165 ± 0.005^{a}
R_0 (offspring/individual)	21.16 ± 2.36^{c}	71.5 ± 6.75^{b}	99.96 ± 11.72^{a}
T **(day)**	53.17 ± 0.87^{a}	51.02 ± 0.90^{b}	30.08 ± 0.53^{c}

Means in a column followed by different letters are significantly different ($P < 0.0001$).

The age-stage survival rate (s_{xj}) shows significant overlapping among different stages, males, and females (Fig. 1) due to the variable developmental rates among individuals according to the age-stage, two-sex life table analysis. The female adult numbers in propargite, and the number of males in fenpyroximate declined in comparison with control individuals (Fig. 1).

The chance of a newly laid egg would survive to the adult stage was in the maximum rate in the control as it was estimated 0.43 for females, and 0.41 for males. On the other hand, in the fenpyroximate treatment, this parameter showed 0.40 and 0.21 for females and males, respectively. Also, it was 0.28 for females and 0.23 for males in the propargite treatment, respectively. In the control, male and female individuals survived until the day 42 and 44, respectively. However, the females and males in the propargite treatment were alive until the day 69 and 70, respectively. In the fenpyroximate treatment, male survival (67) was less than that for the females which were alive until the day 70 (Fig. 1).

Values for the age-specific survival rate (l_x), female age-stage specific fecundity (f_{xj}), age-specific fecundity of the total population (m_x), and age specific maternity (l_xm_x) are presented in Figure 2.

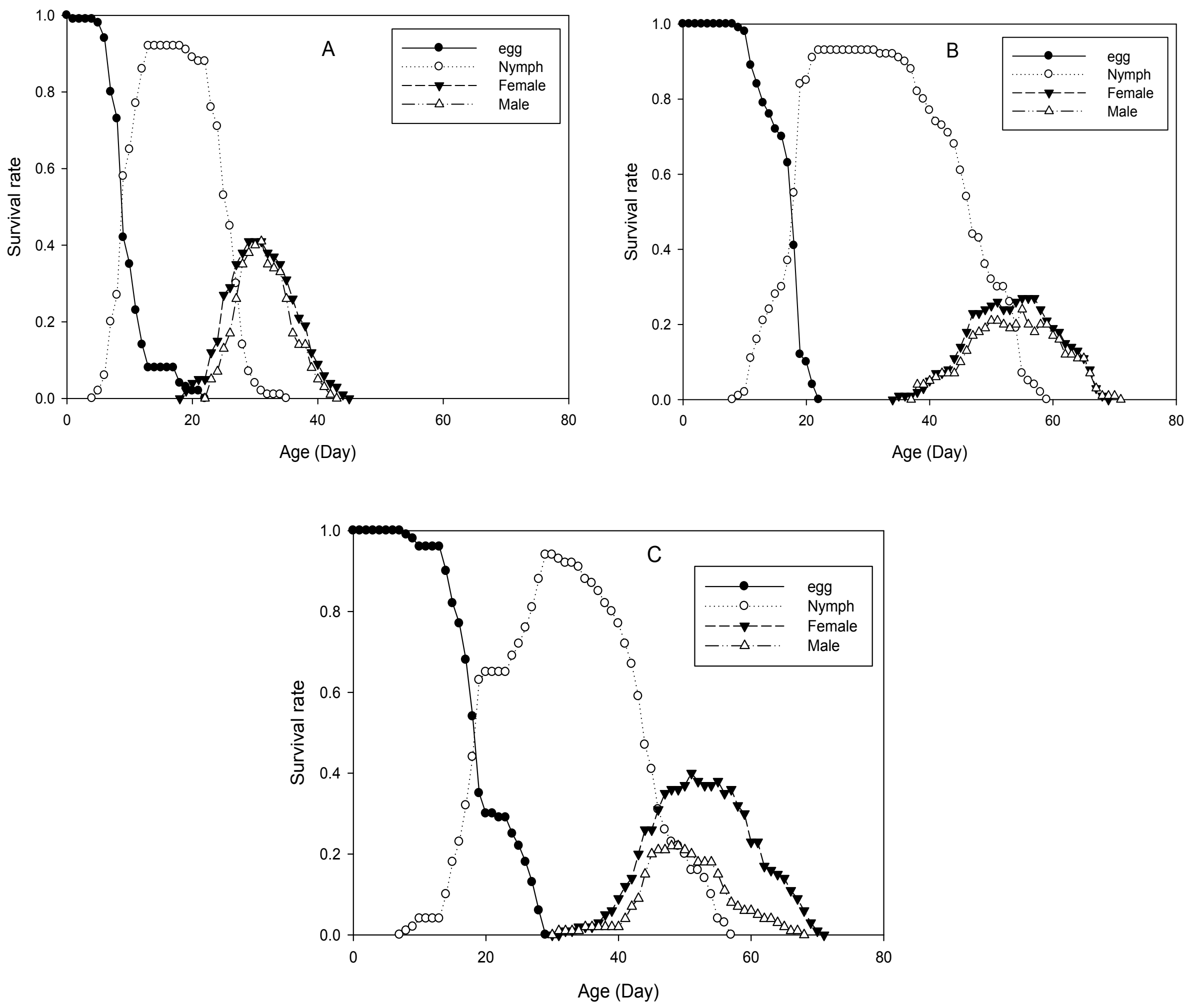

Figure 1. The age-stage specific survival rate (s_{xj}) of *Macrolophus pygmaeus* reared on *Tetranychus urticae* eggs in Control (A), sublethal concentrations (LC_{30}) of propargite (B) and sublethal concentrations (LC_{30}) of fenpyroximate (C) treated individuals.

The maximum age-specific fecundity in the control is in the day 31 with producing 11.07 eggs. This value in maximum rate for the fenpyroximate (day 64), and propargite treatments (day 60) were 9.14 and 3.14, respectively. Also, the maximum value of the female age-stage specific fecundity for the control (day 24), fenpyroximate (day 36), and propargite treatments (day 60) represented 23.73, 14.0 and 6.0, respectively (Fig. 2).

The life expectancy curve (e_{xj}) which is the total time that an individual of age x and stage j is expected to live, for the female individuals in the control when they reached to the adult stage was 30 days. This value for the female adults in the both fenpyroximate and propargite treatments was 20 days (Fig. 3).

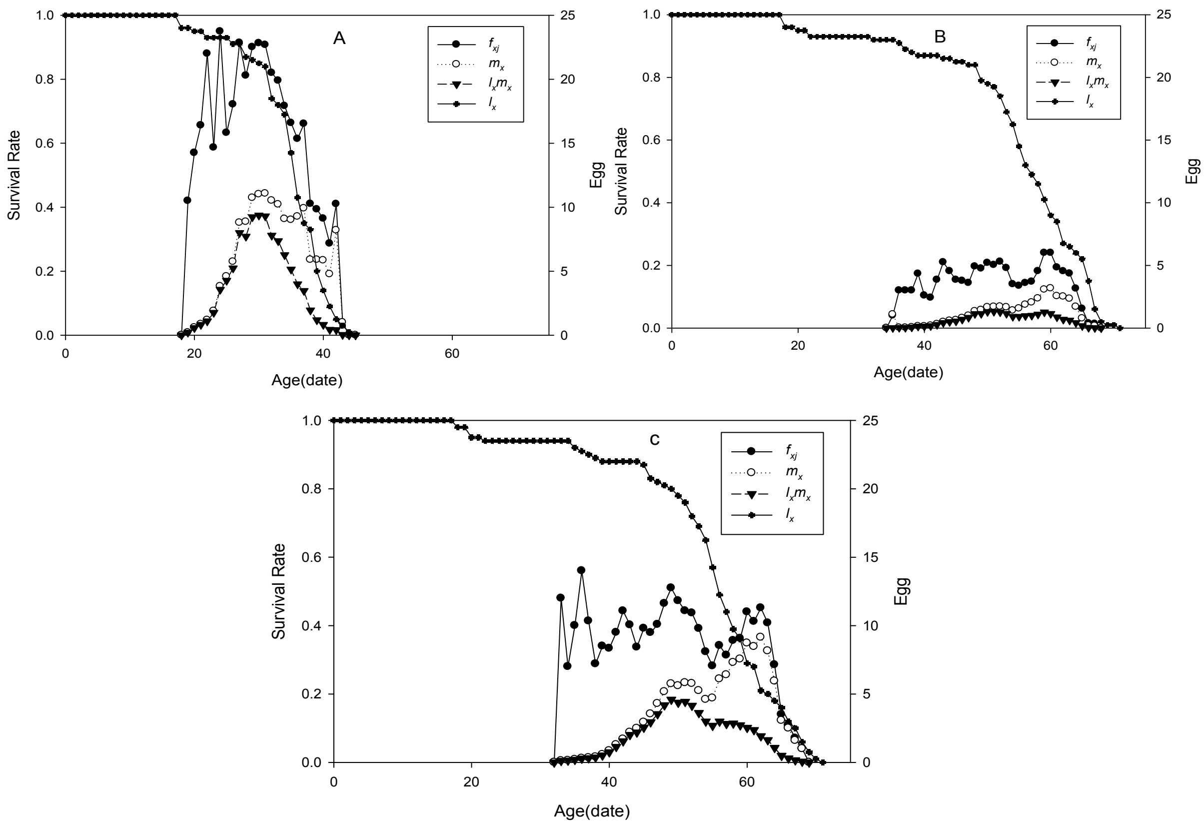

Figure 2. Age-specific survival rate (l_x), female age-stage specific fecundity (f_{xj}), age-specific fecundity (m_x), and age specific maternity (l_xm_x) of *Macrolophus pygmaeus* reared on *Tetranychus urticae* eggs in Control (A), sublethal concentrations (LC_{30}) of propargite (B) and sublethal concentrations (LC_{30}) of fenpyroximate (C) treated individuals.

DISCUSSION

In the current study, lethal and sublethal effects of fenpyroximate and propargite were investigated on the mirid predatory bug, *M. pygmaeus*, for the first time. Both chemicals are among the most low-risk acaricides in controlling a variety of phytophagous mites in greenhouses or the other agricultural system (Sherwani and Mukhtar 2019). In several studies, short- and long-term effects of these pesticides were examined against some natural enemies.

According to our data, LC_{50} values of fenpyroximate and propargite against *M. pygmaeus* adults fed with contaminated *T. urticae* eggs were 5.74 and 3.41 mg(ai)L^{-1}, respectively. According to the mode of action and route of the entry, each chemical can have its special effect on the treated individuals. Therefore, if these two acaricides spray on the predators or we us any other bioassay procedure, we can observe different results. Hamedi *et al*. (2010) showed that the concentrations caused 50% mortality in female and male individuals of *Phytoseius plumifer* (Canestrini & Fanzago), affected by fenpyroximate was 20.20 and 13.49 mg(ai)L^{-1}, respectively. They studied the bioassay experiments using dipping leaf disks into the pesticide solution. On the other hand, using potter tower spraying method, Lima *et al*. (2013) showed that fenpyroximate was very selective to *Neoseiulus baraki* (Athias-Henriot) due to the estimated LC_{50} value of 4997 mg(ai)L^{-1}, which was about 781 times greater than this value in its eriophyid prey, *Aceria guerreronis* Keifer. Rezaei *et al*. (2007) evaluated propargite effect on two-day-old larvae of *Chrysoperla carnea* using residual glass plate bioassay and resulted that this acaricide could be slightly harmful for the predator, according to the

International Organization of Biological Control (IOBC) procedure. In fact, this chemical with concentration of 1425 mg(ai)L^{-1} led to about 36% mortality of this biocontrol agent.

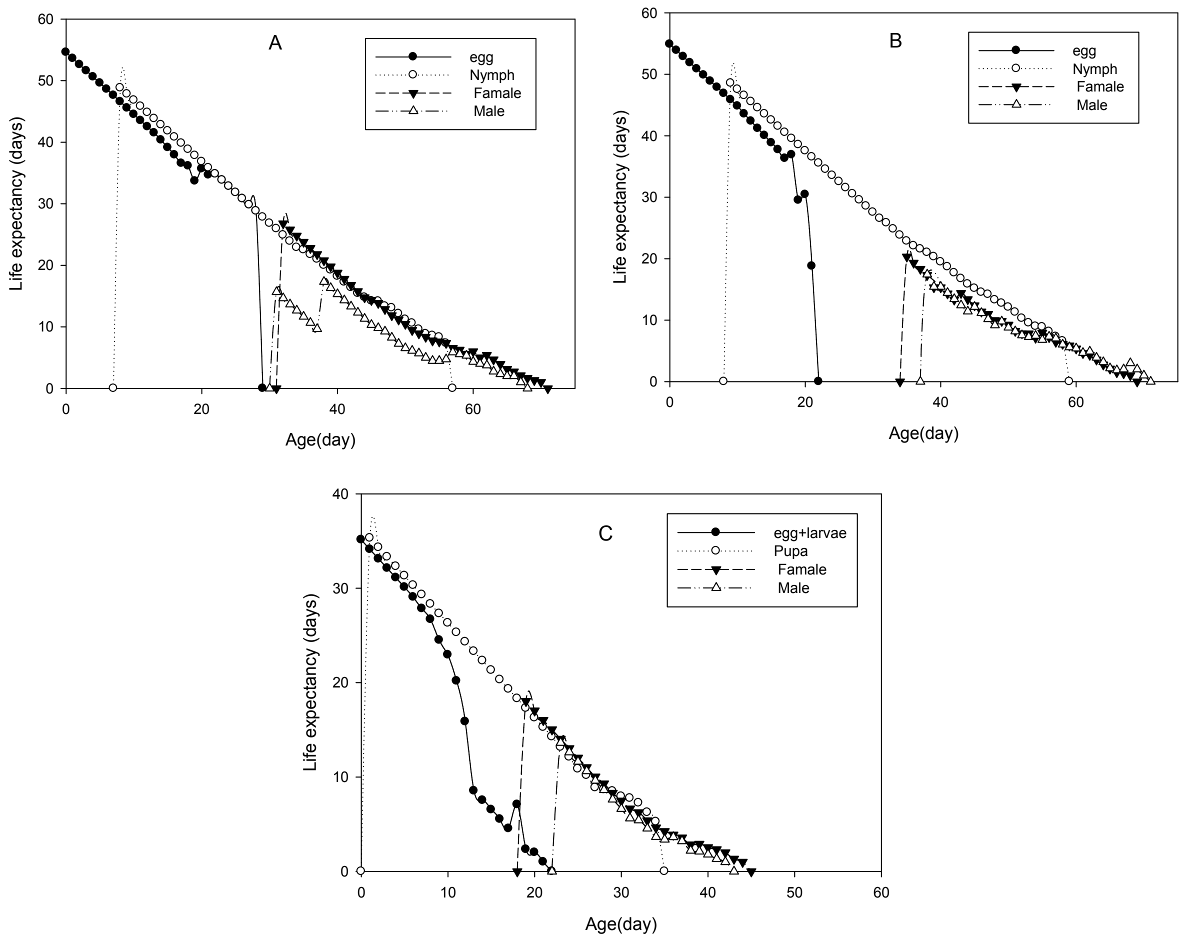

Figure 3. The life expectancy (e_{xj}) of *Macrolophus pygmaeus* reared on *Tetranychus urticae* eggs in Control (A), sublethal concentrations (LC_{30}) of propargite (B) and sublethal concentrations (LC_{30}) of fenpyroximate (C) treated individuals.

One of the reasons about why natural enemies respond to these acaricides differently, could be due to the route of entry of the pesticides. In fact, the non-target arthropods are exposed to pesticides by through different ways such as direct contact with sprayed pesticides, indirect contact with pesticide residues on surface of plants, or through the ingestion of preys contaminated with pesticides (Jepson 1989; Suárez-López *et al.* 2020). For example, Ashley *et al.* (2006) showed that propargite killed all adult individuals of *Orius insidiosus* (Say) one day after direct exposure. However, residual toxicity of this acaricide against the adult stage was varied in different days after treatment and the mortality at 24 hours post-treatment was measured less than 70%. In addition, life stage of the natural enemies is the other critical parameter that influences the pesticides effectiveness (El Aalaoui *et al.* 2019). According to Olszak (1999) results, propargite was nearly harmless to fourth instar larvae, pupae, and adult individuals of two-spotted ladybird, *Adalia bipunctata* L. after immersion in the chemical solution under laboratory conditions. Similarly, propargite was not dangerous for the second and fourth instar larvae of this ladybird after exposure to the chemical residues on apple leaves cut from trees sprayed before.

In this study, life history and demographic parameters were significantly affected by both acaricides in concentrations caused 30% mortality in *M. pygmaeus* adults. Both acaricides could increase longevity of different stages of the predatory bug compared with the control. Since the bug ingested contaminated eggs with these chemicals, maybe inappropriate or poor quality food could increase life duration of this insect. Several studies such as Azimi *et al*. (2020) illustrated negative effects of the inappropriate diet in the growth and developmental rate of the organism.

On the other hand, fecundity of the female adult bugs decreased in both treatments, significantly. Reduction of fecundity as a side-effect of these two chemicals was reported in other studies. Rezaei *et al*. (2007) showed that the number of eggs produced by *C. carnea* female adults treated with propargite was 1.5 times fewer than the control. Also, Hamedi *et al*. (2010) represented that *P. plumifer* affected by sublethal concentrations of fenpyroximate produced fewer eggs. Thus, fecundity of the predatory mite affected by LC_{30} of this acaricide was 43 times less than the control. Theoretically, all classes of pesticides in sublethal concentrations have the potential to affect the arthropod reproduction due to adverse effects on fertilization of egg, oogenesis, ovulation, spermatogenesis, sperm motility, and the other reproductive physiology (Haynes 1988; Muller *et al*. 2019). Evaluation of sublethal effects of the chemicals on biology of natural enemies can be very helpful in taking decisions about the integrated pest management program procedures, because sublethal concentrations do not show obvious effects such as death very clearly, but depict some important effects on the insect biological and ecological traits that even continuing in the next generations (de França *et al*. 2017).

Demographic analysis as a valuable approach, even represent better evaluations of pesticides toxicity against arthropods, since such studies provide total effects of a toxicant on a population during long period of time that are not perceived in short time assay (Stark and Banks 2003). In the present study, population parameters such as intrinsic rate of increase (r), finite rate of increase (λ), net reproductive rate (R_0), and mean generation time (T) were significantly affected by the sublethal concentration (LC_{30}) of propargite and fenpyroximate. This showed that concentration values of 0.756 and 1.25 mg(ai)L^{-1} of both acaricides, respectively could produce harmful effects on the physiology of *M. pygmaeus* during a generation.

Demographic response of various biological control agents to propargite and fenpyroximate were different. Alinejad *et al*. (2020) showed that different sublethal concentrations (LC_{10}, LC_{20}, and LC_{30}) of propargite had no significant effect on the intrinsic rates of increase of *Amblyseius swirskii* in comparison to the control. Also, Saber (2011) did not find any significant changes in life table statistics of *Trichogramma cacoeciae* (Marchal) emerged from its host eggs exposed to field rate of fenpyroximate. On the other hand, fenpyroximate could have harmful effect on intrinsic rate of increase in the treated *P. persimilis* so their population growth trend became negative (r = -0.02 $days^{-1}$) (Ghaderi *et al*. 2013). Residual effect of propargite reduced some biological parameters of *C. carnea* including *r*, while some other ones such as the net reproductive rate increased (Rezaei *et al*. 2007).

According to the company manufacture, LC_{50} value of both acaricides, propargite and fenpyroximate evaluated from the mirid bug, *M. pygmaeus* were higher than the field recommended rate for the two-spotted spider mite (1L/ha). However, the demographic toxicology results achieved in this study represented that the applied concentration (LC_{30}) had negative effects on several parameters of biology and life table of the predator during the generation. Therefore, none of these acaricides are compatible with survival, fecundity, and activity of this effective generalist biological control agent and more care should be taken whenever these chemicals are used in IPM programs. Since natural enemies are also in contact with pesticides spraying on the plants and/or they may be exposed to the chemical residues, additional research is necessary to investigate the different methods of toxicity assay of propargite and fenpyroximate on *M. pygmaeus* for taking better picture about the bug susceptibility to these chemicals.

REFERENCES

Adesanya, A.W., Beauchamp, M.J., Lavine, M.D., Lavine, L.C., Zhu, F. & Walsh, D.B. (2019) Physiological resistance alters behavioral response of *Tetranychus urticae* to acaricides. *Scientific Reports*, 9: 19308.
DOI: 10.1038/s41598-019-55708-4

Ajila, H.E.V., Colares, F., Lemos, F., Marques, P.H., Franklin, E.C., do Vale, W.S., E Oliveira, E., Venzond, M. & Pallinia, A. (2019) Supplementary food for *Neoseiulus californicus* boosts biological control of *Tetranychus urticae* on strawberry. *Pest Management Science*, 75: 1986–1992.
DOI: 10.1002/ps.5312

Alinejad, M., Kheradmand, K. & Fathipour, Y. (2020) Demographic analysis of sublethal effects of propargite on *Amblyseius swirskii* (Acari: Phytoseiidae): Advantages of using age-stage, two sex life table in ecotoxicological studies. *Systematic & Applied Acarology*, 25(5): 906–917.
DOI: 10.11158/saa.25.5.11

Alpkent, Y.N., Inak, E., Ulusoy, S. & Ay, R. (2020) Acaricide resistance and mechanisms in *Tetranychus urticae* populations from greenhouses in Turkey. *Systematic & Applied Acarology*, 25(1): 155–168.
DOI: 10.11158/saa.25.1.12

Amaral, F.S.R.D. & Cavalcante, C.C., Lofego, A.C. (2020) *Amblyseius chiapensis* (Acari: Phytoseiidae) as natural enemy of *Tetranychus urticae* (Acari: Tetranychidae). *Systematic & Applied Acarology*, 25(2): 173–177.
DOI: 10.11158/saa.25.2.1

Arnó, J. & Gabarra, R. (2011) Side effects of selected insecticides on the *Tuta absoluta* (Lepidoptera: Gelechiidae) predators *Macrolophus pygmaeus* and *Nesidiocoris tenuis* (Hemiptera: Miridae). *Journal of Pest Science*, 84: 513–520.
DOI: 10.1007/s10340-011-0384-z

Asadi, M., Rafiee-Dastjerdi, H., Nouri-Ganbalani, G., Naseri, B. & Hassanpour, M. (2018) Lethal and sublethal effects of five insecticides on the demography of a parasitoid wasp. *International Journal of Pest Management*, 65(4): 301-312.
DOI: 10.1080/09670874.2018.1502899

Ashley, J.L., Herbert, D.A., Lewis, E.E., Brewster, C.C. & Huckaba, R. (2006) Toxicity of three acaricides to *Tetranychus urticae* (Acari: Tetranychidae) and *Orius insidiosus* (Hemiptera: Anthocoridae). *Journal of Economic Entomology*, 99(1): 54–59.
DOI: 10.1093/jee/99.1.54

Azimi, S., Rahmani, S. & Maghsoud Pazhouhandeh. (2020) Effect of protein extracts of *Amaranthus retroflexus* (Amaranthaceae) and *Cuminum cyminum* (Apiaceae) on digestive proteinases and biological characters of *Helicoverpa* (*Heliothis*) *armigera* (Hübner) (Lepidoptera: Noctuidae). *The Canadian Entomologist*, 152(5): 646–662.
DOI: 10.4039/tce.2020.28

Castilhos, R.V., Grützmacher, A.D. & Coats, J.R. (2018) Acute toxicity and sublethal effects of terpenoids and essential oils on the predator *Chrysoperla externa* (Neuroptera: Chrysopidae). *Neotropical Entomology*, 47: 311–317.
DOI: 10.1007/s13744-017-0547-6

Chi, H. (1988) Life-table analysis incorporating both sexes and variable development rates among individuals. *Environmental Journal of Entomology*, 17: 26–34.
DOI: 10.1093/ee/17.1.26

Chi, H. (2019) TWOSEX-MSChart: Computer Program for Age-stage, Two-Sex Life Table Analysis. Available from: http://140.120.197.173/Ecology (Accessed on 21 July 2019).

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.
DOI: 10.1603/0046-225X-35.1.10

Chi, H. & Yang, T. (2003) Two-sex life table and predation rate of *Propylaea japonica* Thunberg (Coleoptera: Coccinellidae) fed on *Myzus persicae* (Sulzer) (Homoptera: Aphididae). *Environmental Entomology*, 32: 327–333.
DOI: 10.1603/0046-225X-32.2.327

De Armas, F.S., Grutzmacher, A.D., Nava, D.E., Pasini, R.A., Rakes, M. & de Bastos Pazini, J. (2020) Non-target toxicity of nine agrochemicals toward larvae and adults of two generalist predators active in peach orchards. *Ecotoxicology*, 29: 327–339.
DOI: 10.1007/s10646-020-02177-5

De França, S.M., Breda, M.O., Barbosa, D.R.S., Araujo, A.M.N. & Guedes, C.A. (2017) The Sublethal effects of insecticides in insects. *In*: Shields, V.D.C. (Ed.), *Biological control of pest and vector insects*. *IntechOpen*. Available from: https://www.intechopen.com/books/biological-control-of-pest-and-vector-insects/the-sublethal-effects-of-insecticides-in-insects
DOI: 10.5772/66461.

El Arnaouty, S.A., Kortam, M.N., Afifi, A.I. & Heikal, I.H. (2018) *Orius albidipennis* (Rueter) as an effective biocontrol agent against *Tetranychus urticae* Koch on pepper crops in greenhouse in Egypt. *Egyptian Journal of Biological Pest Control*, 28: 42.
DOI: 10.1186/s41938-018-0045-0

El Aalaoui, M., Bouharroud, R., Sbaghi, M., El Bouhssini, M., Hilali, L. & Dari, K. (2019) Comparative toxicity of different chemical and biological insecticides against the scale insect *Dactylopius opuntiae* and their side effects on the predator *Cryptolaemus montrouzieri*. *Archives of Phytopathology and Plant Protection*, 52(1–2): 155-169.
DOI: 10.1080/03235408.2019.1589909

Ghaderi, S., Minaei, K., Kavousi, A., Akrami, M.A., Aleosfoor, M. & Ghadamyari, M. (2013) Demographic analysis of the effect of fenpyroximate on *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Entomologia Generalis*, 34(3): 225–233.
DOI: 10.1127/entom.gen/34/2013/225

Ghasemzadeh, S. & Qureshi, J.A. (2018) Demographic analysis of fenpyroximate and thiacloprid exposed predatory mite *Amblyseius swirskii* (Acari: Phytoseiidae). *PLoS ONE*, 13(11): e0206030.
DOI: 10.1371/journal.pone.0206030

Gigon, V., Camps, C. & Le Corff, J. (2016) Biological control of *Tetranychus urticae* by *Phytoseiulus macropilis* and *Macrolophus pygmaeus* in tomato greenhouses. *Experimental and Applied Acarology*, 68: 55–70.
DOI: 10.1007/s10493-015-9976-2

Giles, K.L., Mc Cornack, B.P., Royer, T.A. & Elliott, N.C. (2017) Incorporating biological control into IPM decision making. *Current Opinion in Insect Science*, 20: 84–89.
DOI: 10.1016/j.cois.2017.03.009

Golec, J.R., Hoge, B. & Walgenbach, J.F. (2020) Effect of biopesticides on different *Tetranychus urticae* Koch (Acari: Tetranychidae) life stages. *Crop Protection*, 128: 105015.
DOI: 10.1016/j.cropro.2019.105015

Goodman, D. (1982) Optimal life histories, optimal notation, and the value of reproductive value. *The American Naturalist*, 119(6): 803–823.

DOI: 10.2307/2460964
Hamedi, N., Fathipour, Y. & Saber, M. (2010) Sublethal effects of fenpyroximate on life table parameters of the predatory mite *Phytoseius plumifer*. *BioControl*, 55: 271–278. DOI: 10.1007/s10526-009-9239-4
Hassanpour, M., Nouri-Ganbalani, G., Mohaghegh, J. & Enkegaard, A. (2009) Functional response of different larval instars of the green lacewing, *Chrysoperla carnea* (Neuroptera: Chrysopidae), to the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). *Journal of Food, Agriculture & Environment*, 7(2): 424–428. DOI: 10.1234/4.2009.1678
Haynes, K.F. (1988) Sublethal effects of neurotoxic insecticides on insect behavior. *Annual Review Entomology*, 33: 149–168. DOI: 10.1146/annurev.en.33.010188.001053
Herron, G.A., Rophail, J., Holloway, J. & Barchia, I. (2003) Potentiation of a propargite and fenpyroximate mixture against two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). *Experimental and Applied Acarology*, 29: 115–119. DOI: 10.1023/A:1024277711877
Iftikhar, A., Hafeez, F., Hafeez, M., Farooq, M., Asif Aziz, M., Sohaib, M., Naeem, A. & Lu, Y. (2020) Sublethal effects of a juvenile hormone analog, Pyriproxyfen on demographic parameters of non-target predator, *Hippodamia convergens* Guerin-Meneville (Coleoptera: Coccinellidae). *Ecotoxicology*, 29: 1017–1028. DOI: 10.1007/s10646-020-02159-7
Jepson, P.C. (1989) The temporal and spatial dynamics of pesticide side effects on non-target invertebrates. *In*: Jepson, P.C. (Ed.), *Pesticides and Non-Target Invertebrates*. Intercept Ltd, Andover, Dorset, pp. 95–128.
Kim, Y.-J., Lee, S.-H., Lee, S.-W. & Ahn, Y.-J. (2004) Fenpyroximate resistance in *Tetranychus urticae* (Acari: Tetranychidae): cross-resistance and biochemical resistance mechanisms. *Pest Management Science*, 60:1001–1006. DOI: 10.1002/ps.909
Leman, A., Ingegno, B.L., Tavella, L., Janssen, A. & Messelink, G.J. (2020) The omnivorous predator *Macrolophus pygmaeus*, a good candidate for the control of both greenhouse whitefly and poinsettia thrips on gerbera plants. *Insect Science*, 27: 510–518. DOI: 10.1111/1744-7917.12655
LeOra Software (1997) POLO-PC: A User Guide to Probit or Logit Analysis. LeOra Software, Berkeley, California, USA.
Liang, X., Chen, Q., Wu, C. & Zhao, H. (2018) The joint toxicity of bifenazate and propargite mixture against *Tetranychus urticae* Koch. *International Journal of Acarology*, 44(1): 35–40. DOI: 10.1080/01647954.2017.1398276
Lima, D.B., Monteiro, V.B., Guedes, R.N.C., Siqueira, H.A.A., Pallini, A. & Gondim, M.G.C. Jr. (2013) Acaricide toxicity and synergism of fenpyroximate to the coconut mite predator *Neoseiulus baraki*. *BioControl*, 58: 595–605. DOI: 10.1007/s10526-013-9520-4
Lira, A.C.S., Zanardi, O.Z., Belot, V.H., Bordini, G.P., Yamamoto, P.T., Parra, J.R.P. & Carvalho, G.A. (2015) Lethal and sublethal impacts of acaricides on *Tamarixia radiata* (Hemiptera: Eulophidae), an important ectoparasitoid of *Diaphorina citri* (Hemiptera: Liviidae). *Journal of Economic Entomology*, 108(5): 2278–2288. DOI: 10.1093/jee/tov189
Lopez, L., Smith, H. A., Hoy, M.A. & Bloomquist, J. R. (2015) Acute toxicity and sublethal effects of Fenpyroximate to *Amblyseius swirskii* (Acari: Phytoseiidae). *Journal of Economic Entomology*, 108(3): 1047–1053. DOI: 10.1093/jee/tov033

Lykouressis, D.P., Perdikis, D.Ch. & Gaspari, M.D. (2007) Prey preference and biomass consumption of *Macrolophus pygmaeus* (Hemiptera: Miridae) fed *Myzus persicae* and *Macrosiphum euphorbiae* (Hemiptera: Aphididae). *European Journal of Entomology*,104: 199–204. DOI: 10.14411/eje.2007.031

Martinou, A.F. & Stavrinides M.C. (2015) Effects of sublethal concentrations of insecticides on the functional response of two mirid generalist predators. *PLoS ONE*, 10(12): e0144413. DOI: 10.1371/journal.pone.0144413

Martinou, A.F., Seraphides, N., & Stavrinides, M.C. (2014) Lethal and behavioral effects of pesticides on the insect predator *Macrolophus pygmaeus*. *Chemosphere*, 96: 167–173. DOI: 10.1016/j.chemosphere.2013.10.024

Mena, Y.M., Mesa, N.C., Escobar, A. & Perez, S. (2020) Evaluation of Phytoseiidae mites and *Chrysoperla carnea* (Stephens) on the control of *Tetranychus urticae* in *Carica papaya* L. *Agronomía Colombiana*, 38(1): 101-109. DOI: 10.15446/agron.colomb.v38n1.73271

Mortazavi, N., Fathipour, Y. & Talebi, A.A. (2019) The efficiency of *Amblyseius swirskii* in control of *Tetranychus urticae* and *Trialeurodes vaporariorum* is affected by various factors. *Bulletin of Entomological Research*, 109(3): 365–375. DOI: 10.1017/S0007485318000640

Motoba, K., Suzuki, T. & Uchida, M. (1992) Effect of a new acaricide, fenpyroximate, on energy metabolism and mitochondrial morphology in adult female *tetranychus urticae* (two-spotted spider mite). *Pesticide Biochemistry and Physiology*, 43: 37–44. DOI: doi.org/10.1016/0048-3575(92)90017-T

Muller, T., Romer, C.I. & Muller, C. (2019) Parental sublethal insecticide exposure prolongs mating response and decreases reproductive output in offspring. *Journal of Applied Ecology*, 56(7): 1528–1537. DOI: 10.1111/1365-2664.13398

Olszak, R.W. (1999) Influence of some pesticides on mortality and fecundity of the aphidophagous coccinellid *Adalia bipunctata* L. (Col., Coccinellidae). *Journal of Applied Entomology*, 123: 41–45. DOI: 10.1046/j.1439-0418.1999.00314.x

Park, J.-J., Kim, M., Lee, J.-H., Shin, K.-I., Lee, S.E., Kim, J.-G. & Cho, K. (2011) Sublethal effects of fenpyroximate and pyridaben on two predatory mite species, *Neoseiulus womersleyi* and *Phytoseiulus persimilis* (Acari, Phytoseiidae). *Experimental and Applied Acarology*, 54: 243–259. DOI: 10.1007/s10493-011-9435-7

Passos, L.C., Soares, M.A., Collares, L.J., Malagoli, I., Desneux, N. & Carvalho, G.A. (2018) Lethal, sublethal and transgenerational effects of insecticides on *Macrolophus basicornis*, predator of *Tuta absoluta*. *Entomologia Generalis*, 38(2): 127–143. DOI: 10.1127/entomologia/2018/0744

Perdikis, D. & Lykouressis, D. (2000) Effects of various items, host plants, and temperatures on the development and survival of *Macrolophus pygmaeus* Rambur (Hemiptera: Miridae). *Biological Control*, 17: 55–60. DOI: 10.1006/bcon.1999.0774

Perdikis, D.Ch. & Lykouressis, D.P. (2002) Life table and biological characteristics of *Macrolophus pygmaeus* when feeding on *Myzus persicae* and *Trialeurodes vaporariorum* Dionyssios. *Entomologia Experimentalis et Applicata*, 102: 261–272. DOI: 10.1046/j.1570-7458.2002.00947.x

Pérez-Aguilar, D.A., Soares, M.A., Passos, L.C., Martínez, A.M., Pineda, S. & Carvalho, G.A. (2018) Lethal and sublethal effects of insecticides on *Engytatus varians* (Heteroptera: Miridae), a predator of *Tuta absoluta* (Lepidoptera: Gelechiidae). *Ecotoxicology*, 27: 719–728.

DOI: 10.1007/s10646-018-1954-0

Rahman, Md.A., Sarker, S., Ham, E., Lee, J.-S. & Lim, U.T. (2020) Development and fecundity of *Orius minutus* (Hemiptera: Anthocoridae) and *O. laevigatus* reared on *Tetranychus urticae* (Acari: Tetranychidae). *Journal of Economic Entomology*, 113(4): 1735–1740. DOI: 10.1093/jee/toaa078

Rahmani, S. & 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. DOI: 10.1016/j.cropro.2013.08.002

Rahmani, S., Azimi. S. & Moghadasi, M. (2016) LC_{30} effects of thiamethoxam and pirimicarb, on population parameters and biological characteristics of *Macrolophus pygmaeus* (Hemiptera: Miridae). *Arthropods*, 5(2): 44–55.

Rezaei, M., Talebi, K., Naveh, V.H. & Kavousi, A. (2007) Impacts of the pesticides imidacloprid, propargite, and pymetrozine on *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae): IOBC and life table assays. *BioControl*, 52: 385–398. DOI: 10.1007/s10526-006-9036-2

Ricupero, M., Abbes, K., Haddi, K., Kurtulus, A., Desneux, N., Russo, A., Siscaro, G., Biondi, A. & Zappalà, L. (2020) Combined thermal and insecticidal stresses on the generalist predator *Macrolophus pygmaeus*. *Science of the Total Environment*, 729: 138922. DOI: 10.1016/j.scitotenv.2020.138922

Rott, A.A.S. & Ponsonby, D.J. (2000) Improving the control of *Tetranychus urticae* on edible glasshouse crops using a specialist coccinellid (*Stethorus punctillum* Weise) and a generalist mite (*Amblyseius californicus* McGregor) as biocontrol. *Biocontrol Science and Technology*, 10: 487–498. DOI: 10.1080/09583150050115070

Saber, M. (2011) Acute and population level toxicity of imidacloprid and fenpyroximate on an important egg parasitoid, *Trichogramma cacoeciae* (Hymenoptera: Trichogrammatidae). *Ecotoxicology*, 20: 1476–1484. DOI: 10.1007/s10646-011-0704-3

Suárez-López, Y.A., Hatem, A.E., Aldebis, H.K. & Vargas-Osuna, E. (2020) Lethal and sublethal effects of lufenuron on the predator *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), *Crop Protection*, 135: 105217. DOI: 10.1016/j.cropro.2020.105217

Shaef Ullah, M. & Lim, U.T. (2017) Synergism of *Beauveria bassiana* and *Phytoseiulus persimilis* in control of *Tetranychus urticae* on bean plants. *Systematic & Applied Acarology*, 22(11): 1924–1935. DOI: 10.11158/saa.22.11.11

Shah, R. & Appleby, M. (2019) Testing the contact and residual toxicity of selected low-risk pesticides to *Tetranychus urticae* Koch and its predators. *Sarhad Journal of Agriculture*, 35(4): 1113–1121. DOI: 10.17582/journal.sja/2019/35.4.1113.1121

Sharifian, I., Sabahi, Q. & Bandani, A.R. (2017) Effect of some conventional insecticides on functional response parameters of *Macrolophus pygmaeus* (Hem.: Miridae) on *Tuta absoluta* (Lep.: Gelechiidae). *Biharean Biologist*, 11(1): 10–4.

Sherwani, S.A. & Mukhtar, M. (2019) Persistence and residual toxicity of propargite against *Panonychus ulmi* Koch (Acari: Tetranychidae) on *Malus domestica* Borkh. *Journal of Pharmacognosy and Phytochemistry*, 8(4): 1320–1323.

Shiraishi, Y., Murai, M., Sakiyama, N., Ifuku, K. & Miyoshi H. (2012) Fenpyroximate binds to the interface between PSST and 49 kDa subunits in mitochondrial NADH-ubiquinone oxidoreductase. *Biochemistry*, 51(9): 1953–1963.

DOI: 10.1021/bi300047h

Soares, M.A., Carvalho, G.A., Campos, M.R., Passos, L.C., Haro, M.M., Lavoir, A.-V., Biondi, A., Zappalà, L. & Desneux, N. (2020) Detrimental sublethal effects hamper the effective use of natural and chemical pesticides in combination with a key natural enemy of *Bemisia tabaci* on tomato. *Pest Management Science*, 76(11): 3551–355.
DOI: 10.1002/ps.5927

Solmaz, E, Çevik, B. & Ay, R. (2020) Abamectin resistance and resistance mechanisms in *Tetranychus urticae* populations from cut flowers greenhouses in Turkey, *International Journal of Acarology*, 46(2): 94–99.
DOI: 10.1080/01647954.2020.1727009

Song, Z.-W., Zheng, Y., Zhang, B.-X. & Li, D.-S. (2016) Prey consumption and functional response of *Neoseiulus californicus* and *Neoseiulus longispinosus* (Acari: Phytoseiidae) on *Tetranychus urticae* and *Tetranychus kanzawai* (Acari: Tetranychidae). *Systematic & Applied Acarology*, 21(7): 936–946.
DOI: 10.11158/saa.21.7.7

Stanley, J. & Preetha, G. (2016) Pesticide toxicity to arthropod predators: exposure, toxicity and risk assessment methodologies. *In*: Pesticide toxicity to non-target organisms. Springer, Dordrecht.
DOI: 10.1007/978-94-017-7752-0_1

Stark, J.D. & Banks, J.E. (2003) Population-level effects of pesticides and other toxicants on arthropods. *Annual Review of Entomology*, 48: 505–519.
DOI: 10.1146/annurev.ento.48.091801.112621

Urbaneja, A., Monton, H. & Molla, O. (2009) Suitability of the tomato borer *Tuta absoluta* as prey for *Macrolophus pygmaeus* and *Nesidiocoris tenuis*. *Journal of Applied Entomology*, 133: 292–296.
DOI: 10.1111/j.1439-0418.2008.01319.x

Wilson, L.J., Herron, G.A., Leigh, T.F. & Rophail, J. (1995) Laboratory and field evaluation of the selective acaricides Dicofol and Propargite for control of *Tetranychus urticae* Koch (Acari: Tetranychidae) in Australian cotton. *Journal of the Australian Entomological Society*, 34: 247–252.
DOI: 10.1111/j.1440-6055.1995.tb01332.x

Yang, Y., Li, W., Xie, W., Wu, Q., Xu, B., Wang, S., Li, C. & Zhang, Y. (2015) Development of *Bradysia odoriphaga* (Diptera: Sciaridae) as affected by humidity: An age-stage, two-sex, life-table study. *Applied Entomology and Zoology*, 50: 3–10.
DOI: 10.1007/s13355-014-0295-6

Zhang, N.X., Messelink, G.J., Alba, J.M., Schuurink, R.C., Kant, M.R. & Janssen, A. (2018) Phytophagy of omnivorous predator *Macrolophus pygmaeus* affects performance of herbivores through induced plant defenses. *Oecologia*, 186: 101–113.
DOI: 10.1007/s00442-017-4000-7

اثرات زیرکشنده دو کنه‌کش پروپارژیت و فن‌پیروکسی‌میت بر دورهٔ زندگی *Macrolophus pygmaeus* (Hemiptera: Miridae) پرورش یافته با تخم‌های کنهٔ تارتن دولکه‌ای

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چکیده

کنهٔ (Rambur) *Macrolophus pygmaeus* شکارگری عمومی است که به طور طبیعی و نیز به صورت تجاری به عنوان عامل مهار زیستی انواع زیادی از بندپایان آفت محصولات کشاورزی مورد استفاده قرار می‌گیرد. از آن جایی که سازگاری آفت‌کش‌ها با دشمنان طبیعی از جمله نگرانی‌های مهم در برنامه‌های مدیریت تلفیقی آفات به شمار می‌آید، هدف از بررسی حاضر ارزیابی اثرات جانبی دو کنه‌کش پروپارژیت و فن‌پیروکسی‌میت است که به طور گسترده‌ای برای کنترل کنه‌های گیاهخوار مورد استفاده قرار می‌گیرند. در آزمایش‌های زیست‌سنجی، افراد بالغ *M. pygmaeus* در مدت زمان ۲۴ ساعت با تخم‌های کنهٔ تارتن دولکه‌ای غوطه‌ور شده در غلظت‌های مختلف هر یک از دو ترکیب تغذیه می‌شدند. بر اساس آنالیز پروبیت، LC_{50} تیمارهای پروپارژیت و فن‌پیروکسی‌میت، به ترتیب ۳/۴۱ و ۵/۷۴ (میلی گرم ماده مؤثر بر لیتر) برآورد شدند. ارزیابی دموگرافی با میزان LC_{30} هر یک از کنه‌کش‌ها و با استفاده از جدول زندگی دو جنسی ویژه سن-مرحله زیستی صورت پذیرفت. نتایج نشان داد که هر دو ترکیب شیمیایی اثرات معنی‌داری بر طول دورهٔ رشد و نمو تمامی مراحل زیستی، کل دورهٔ پیش از تخم‌گذاری (TPOP)، دوره پیش از تخم‌گذاری افراد بالغ (APOP) و باروری جنس ماده داشتند. همچنین، تمامی آماره‌های مهم جمعیت تحت تأثیر غلظت‌های زیرکشنده قرار گرفتند. نرخ ذاتی افزایش جمعیت (r) در تیمار شاهد، ۰/۱۵ (در روز) برآورد شد. در حالی که این پارامتر در تیمار پروپارژیت و فن‌پیروکسی‌میت به ترتیب به ۰/۰۵۷ و ۰/۰۸۳ (در روز) کاهش پیدا کرد. میزان خالص تولید مثل (R_0) در تیمارهای شاهد، پروپارژیت و فن‌پیروکسی‌میت به ترتیب ۹۹/۹۶، ۲۱/۱۶ و ۷۱/۵ (فرزند به ازای هر فرد) برآورد شد. طول دورهٔ یک نسل (T) در شاهد ۳۰/۰۸ (روز) مشاهده شد در حالی که این آماره برای حشرات تیمار شده با غلظت‌های زیرکشنده پروپارژیت و فن‌پیروکسی‌میت به ترتیب ۵۳/۱۷ و ۵۱/۰۲ روز بود. نتایج به دست آمده در این بررسی نشان داد هر دو کنه کش مورد استفاده می‌توانند اثرات نامطلوبی بر این شکارگر داشته باشند. بنابراین، استفاده از این دو ترکیب در برنامه‌های مدیریت تلفیقی آفات سامانه‌های کشاورزی که این سن خانوادهٔ Miridae به عنوان عامل مهار زیستی در آنها فعالیت دارد، نامناسب تشخیص داده شد.

واژگان کلیدی: زیست‌سنجی؛ سن؛ مدیریت تلفیقی آفات؛ جدول زندگی؛ *Tetranychus urticae*.

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