Sublethal Effects of Three Insecticides on Life History Parameters of *Oenopia conglobata contaminata*, an Important Predatory Coccinellid of *Agonoscena pistaciae*

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Abstract

Introduction: The predatory ladybeetle, *Oenopia conglobata contaminata* (L.) (Col. Coccinellidae), is an important coccinellid predator of the common pistachio psylla, *Agonoscena pistaciae* Burckhardt and Lauterer (Hem.: Psyllidae). Given public concerns about reducing dependence on chemical pesticides in pistachio orchards, the use of biological control agents is attracting growing attention.

Materials and Methods: In this study, effects of spirotetramat, fenitrothion, and chlorpyrifos (350, 40, and 10 ml/L, respectively) on some biological and life history parameters of *O. conglobata contaminata* fed on the common pistachio psylla were examined under controlled conditions (25 ± 1°C, 60 ± 5% RH, and 16:8 h L: D photoperiod). Accordingly, eggs of *O. conglobata contaminata* were exposed to pesticides by a dipping method.

Results: The results revealed that spirotetramat, fenitrothion, and chlorpyrifos decreased the development time and total longevity in *O. conglobata contaminata* adults. The highest and lowest fecundity rates were observed in spirotetramat and fenitrothion treatments, respectively. The treatments of insecticides exerted adverse effects on life history parameters of *O. conglobate contaminata*. The highest values of r, R_0, λ, and *GRR* were obtained in the spirotetramat treatment, whereas the lowest values of these population parameters were recorded in the fenitrothion treatment.

Conclusion: The results suggest that spirotetramat could be effective in *O. conglobata contaminata* in an IPM program.

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1. Introduction

The common pistachio psyllid, *Agonoscena pistaciae* Burckhardt and Lauterer (Hem.: Psyllidae), is the major pest in pistachio orchards of Iran. Both nymphs and adults of the pistachio psyllid damage leaves by a sap-sucking act, thereby producing honeydew. The resulting severe damage could cause decreased plant stability, defoliation, stunning, poor yield, and bud drop [1]. Chemical pesticides are the most practical means of reducing the pest population and preventing their damage during seasonal growth of pistachios. Pesticides and generalist predators, such as coccinellids, usually play a major role in furthering integrated pest management (IPM) programs for this pest [2]. Coccinellids have a great economic effect, during their larval and adult stages, on various soft-bodied crop pests, such as aphids, coccids, and psyllids [3]. Conservation and augmentation of coccinellid predators are at the centre of IPM programs targeting haustellate pests; however, they are frequently reduced by the incompatibility between predators and insecticides used in the crops to control different pest species. In an IPM program, predators play the main role and could be affected by direct contact with fresh sprays [4]. One of the major purposes of IPM strategies is to combine selective pesticides with biological control organisms. Continuous use of insecticides has harmful effects on natural enemies because these useful species are more sensitive than their preys or hosts [5]. Due to multiple generations and the high reproduction ability of *A. pistaciae*, continuous use of pesticides for many years has caused several problems in production of pistachios, including pesticide resistance, destruction of natural enemies of pests, severe pest outbreaks, and sometimes pesticide residues remaining in the crop. Beneficial arthropods, such as predators and parasitoids, could be exposed to insecticides by direct and indirect contact in three main ways, including exposure to insecticide droplets, uptake of residues in contact with plant and soil surface, as well as oral uptake of contaminated preys, nectars, or honeydew [6]. Therefore, lethal and sublethal impacts of pesticides on natural enemies are required to be exerted prior to implementation of IPM programs [7]. Synthetic insecticides are very effective in controlling sucking pests [8]. As a major concern, it is necessary to make natural enemies adapt to pesticides and attempt to incorporate natural enemies, such as coccinellids, into integrated pest management (IPM); however, ladybirds give variable responses when exposed to lethal or sublethal doses of pesticides [9].

It is known that susceptibility of beneficial arthropods to insecticides depends on the pesticide exposure route. Thus, research on effects of insecticides on natural enemies should consider the tritrophic system of predators, preys, and plants to provide valuable information. *Oenopia* (*Synharmonia*) *conglobata contaminata* (L.) (Col.: Coccinellidae) is known to be restricted to deciduous trees. In addition, it is a common coccinellid predator in Europe and Asia [10]. *O. conglobata contaminata* is the major predator of *A. pistaciae*, i.e. the main pistachio pest, in Iran. Field observations in Southeastern Iran show that *O. conglobata contaminata* is one of the most abundant coccinellids in pistachio trees from April to October [11]. This predator often prefers to remain on psyllid-infested pistachio leaves even when aphids, especially cotton aphids, i.e. *Aphis gossypii* (Glover) (Hem.: Aphididae), are abundant on herbaceous plants, such as *Alhagi* sp., in pistachio orchards [12].

A tetramic acid derivative insecticide acts as a lipid biosynthesis inhibitor, especially in immature stages [13]. Chlorpyrifos is a broad-spectrum insecticide that has contact, stomach, and fumigant effects on pests by affecting their survival and developmental time. Besides, fenitrothion is an organophosphorus pesticide that acts as an acetyl cholinesterase inhibitor [14, 15]. However, in the last few years, several studies have reported lethal and sublethal effects of pesticides on non-target organisms, including effects of spirotetramat on *Cryptolaemus montrouzieri* Mulsant (Col.; Coccinellidae) [16] and *Orius insidious* (Hem.: Anthocoridae) [17]. In addition, susceptibility to chlorpyrifos and fenitrothion has been reported in several coccinellids [18, 19].

Although several experimental studies have evaluated effects of pesticides on coccinellid predators, few studies have addressed impacts of pesticides on *O. conglobata contaminata* [20]. In the IPM program, specific effects of the selective pesticide should be maximized on pests but minimized on non-target organisms. Besides, pesticides should be nontoxic to natural enemies and save their natural or augmented populations [21]. The current study investigated sublethal effects of three insecticides on development and life history parameters of *O. conglobata contaminata* under controlled conditions. Spirotetramat, a tetramic acid derivative insecticide and two organophosphorus compounds, including fenitrothion and chlorpyrifos are commonly and abundantly used in pistachio orchards of Rafsanjan. Life history experiments have been conducted to estimate toxic effects of lethal and sublethal concentrations, which provide more information on side effects of pesticides on survival of natural enemies and demographic parameters [21, 22].

This study aims to determine sublethal effects of the aforementioned three pesticides on life history parameters of *O. conglobata contaminata*. Information provided by this study could lead to more efficient use of this predator in integrated pest management programs of *A. pistaciae*.

2. Materials and Methods

2-1- Predator

A laboratory colony of *O. conglobata contaminata* was collected from pistachio orchards, Rafsanjan, Kerman province, Iran, and maintained under controlled conditions of 25± 1ºC, 60±5% relative humidity, and the photoperiod of 16:8 (L: D) h. The predator was reared in an air ventilated plastic box (25× 20× 10 cm) on fresh pistachio leaves infected with nymphs of *A. pistaciae*, which were collected from pistachio trees of the Faculty of Agriculture, Vali-e-Asr University of Rafsanjan,Iran. Besides, a source of food as well as a piece of soaked cotton in a small plastic dish were used to provide food and water to the ladybirds.

2-2- Preys

A number of pistachio seedlings were planted in a plastic pot (35 cm height × 20 cm diameter) filled with a standard potting mix under greenhouse conditions in cages (80× 60× 70 cm) enclosed with a fine mesh lace, with a number of *A. pistaciae* released in the cages. The nymphs of the next generations were used as preys in all experiments. The preys were reared under the same conditions (25± 1ºC, 60±5% RH, and a photoperiod of 16:8 L: D h).

2-3- Insecticides

Commercial formulations of the three insecticides were selected based on the current use and potential effects of the management of *Agonoscena pistaciae*. Spirotetramat (Movento, 10% SC, Bayer Crop Science, Germany), organophosphate fenitrothion (Sumithion, 50% EC, Golsam, Iran) and chlorpyrifos (Dursban, 40% EC, Partonar, Iran) were tested at 350, 40, and 10 mg/l, respectively.

2-4- Sublethal Effects of spirotetramat, fenitrothion, and chlorpyrifos on life table parameters of *O. conglobata contaminata*

Paired *O. conglobata contaminata* were obtained from the colony and fed on *A. pistaciae* in air ventilated plastic boxes. At the beginning of the experiments, to obtain same-age egg batches of *O. conglobata contaminata* (<24 h old), 10 pairs of coccinellids were transferred to ventilated Petri dishes (9×1 cm). After 24 h, the new eggs were isolated in the experimental units up to 30 replicates per treatment, and the test compounds were assessed by a dipping test. Next, pistachio leaves containing egg batches of the predator were dipped in each pesticide for five seconds. The treated leaves were left to dry under room conditions, and then each batch of eggs was placed in separate Petri dishes. The incubation period and survival of the eggs were checked once per 24 h. The newly molted first instars of *O. conglobata contaminata* were reared individually in Petri dishes (9×1 cm) and fed on *A. pistaciae* ad libitum. The development time and survival rate of each instar of *O. conglobata contaminata* were recorded and upon emergence, the adults were allowed to mate; thus, they were placed together in rearing boxes and given the same food as in the larval stage. A total of 10 new mating adult pairs were collected from each treatment, after which, the mating pairs were transferred to separate ventilated Petri dishes (12×1 cm). Next, oviposition and survival were recorded on a daily basis until they died.

2-5- Statistical analysis

The life history parameters were analyzed using raw data from treated *O. conglobata contaminata* based on the age-stage theory and the two-sex life table using TWOSEX-MSChart [23]. Next, the mean and standard errors of the life table parameters were estimated according to the bootstrap technique [24]. Accordingly, the age-stage specific survival rate (S_{xj}), age-stage specific fecundity (f_{xj}), age-stage total fecundity (Ft_{xj}), age-specific survival rate (l_x), age-specific fecundity (m_x), age-stage life expectancy (e_{xj}), age-specific maternity ($l_x m_x$), and life history parameters (r is the intrinsic rate of increase, R_0 denotes the net reproductive rate, and λ is the finite rate of increase) were calculated using the paired bootstrap.

Differences in biological parameters, including the development time, reproductive period, and fecundity were analyzed by the one-way ANOVA and the Tukey's test. Prior to the analysis, data were checked for normality using the Kolmogorov-Smirnov test and for homoscedasticity using the Levene's test.

3. Results

3-1- Sublethal effects of spirotetramat, fenitrothion, and chlorpyrifos on developmental time of *O. conglobata contaminata*

The results revealed that all tested insecticides had significant effects on the developmental duration of *O. conglobate contaminata* (Table 1). Significant differences were found between all treatments in the egg incubation period. Accordingly, spirotetramat increased the incubation period to 3.73±0.10 days, whereas fenitrothion and chlorpyrifos decreased it to 2.50±0.09 and 2.46±0.11 days, respectively. The results showed the first and second larval stages were affected by different insecticide treatments (first instar: $F= 3.753$, $df= 3, 116$, $P<0.05$; second instar: $F=2.069$, $df=3, 116$, $P<0.05$).

Table 1- Developmental time (days) of *Oenopia conglobata contaminata* fed on nymphs of *Agonoscena pistaciae and* exposed to different insecticides and the water dipping test

Developmental stage		Developmental time (days)			
		Insecticides			
		Control	Spirotetramat	Fenitrothion	Chlorpyrifos
Egg		3.06±0.18 [b]	3.73±0.10 [a]	2.50±0.09 [c]	2.46±0.11 [c]
First instar		1.80±0.08 [a]	1.43±0.11 [ab]	1.36±0.12 [b]	1.36±0.10 [b]
Second instar		2.10±0.27 [a]	1.73±0.12 [a]	1.26±0.07 [c]	1.53±0.02 [b]
Third instar		1.83±0.14 [a]	1.66±0.06 [a]	1.46±0.07 [b]	1.33±0.03 [c]
Fourth instar		2.10±0.17[a]	2.10±0.21 [a]	1.96±0.22 [ab]	1.46±0.19 [b]
Pre pupa		1.00±0.00 [a]	1.00±0.00 [a]	1.00±0.00 [a]	1.00±0.00 [a]
Pupa		3.03±0.23 [a]	2.66±0.25 [a]	2.73±1.29 [a]	2.50±0.31 [a]
Pre Adult		14.13±1.07 [b]	12.86±1.20 [b]	11.23±1.16 [b]	10.03±1.23 [b]
Adult	Female	21.20±0.82 [a]	19.50±0.44 [b]	16.16±0.69 [d]	18.43±0.24 [c]
	Male	22.80±0.52 [a]	17.53±0.99 [b]	12.66±0.10 [c]	11.66±0.31 [d]
Total longevity		**58.80±3.99 [a]**	**51.17±3.18 [b]**	**41.20±3.78 [c]**	**41.47±4.58 [c]**

Means± SE; means within a row followed by different letters are significantly different (the Tukey's test; P< 0.05)

Effects of the insecticides on the third and fourth instars of *O. conglobata contaminata* revealed that chlorpyrifos significantly decreased the developmental time (third instar: F= 1.775, df= 3, 116, P< 0.05; fourth instar: F= 2.289, df= 1, 116, P< 0.05), but no differences were observed between spirotetramat and the control in the second, third, and fourth instars of *O. conglobate contaminata*. Besides, there were no significant differences observed between the development time of pre-pupal and pupal stages among all insecticides tested (Pre-pupa: F=0.841, df=3, 116, P>0.05; pupa: F=0.647, df=3, 116, P> 0.05). Effects of insecticides on the adult developmental time showed significant differences between sexes (Female: F= 0.238, df= 3, 116, P< 0.05; Male: F= 1.832, df= 3, 116, P< 0.05). In addition, total longevity was significantly different among all tested insecticides (F= 4.19, df= 3,116, P< 0.05) (Table 1).

3-2- Effects of spirotetramat, fenitrothion, and chlorpyrifos on oviposition and life table parameters

As Table 2 shows, reproduction parameters were affected by insecticides. In addition, the adult pre-oviposition period (APOP) of *O. conglobata contaminata* was significantly different among the tested insecticides (F= 3.472; df= 3, 44; P< 0.05). Besides, fenitrothion and chlorpyrifos significantly increased the total pre-oviposition period (TPOP) (F= 0.774; df= 3, 44; p < 0.05).

The longest APOP and TPOP were observed in adults exposed to chlorpyrifos, with 7.67 and 21.83 days, respectively. The spirotetramat treatment showed highest fecundity (418.75± 39.44) and had a significant difference with other treatments (F= 42.714; df= 3, 44; P< 0.05) (Table 2). Besides, fecundity was significantly affected by different insecticides (F= 42.714; df= 3, 44; P< 0.05); accordingly, the fenitrothion treatment yielded lowest fecundity.

Table 3 shows population parameters of *O. conglobata contaminata* estimated in different treatments using the bootstrap technique. Accordingly, the intrinsic rate of increase (*r*), net reproduction rate (R_0), and finite rate of increase (λ) were significantly lower in insecticide-treated *O. conglobata* than in the control. In *O. conglobata contaminata* treated with spirotetramat, the highest rates of *r*, *R*0, λ, and *GRR* were observed, whereas the lowest values were recorded for the mentioned population parameters in the fenitrothion treatment. The mean generation time (*T*) showed significant differences among different insecticides, with the longest and shortest time periods for this parameter having been observed in spirotetramat (32.06 days) and chlorpyrifos (29.85 days) treatments, respectively (Table 3). Besides, the gross reproductive rate (*GRR*) was significantly higher in spirotetramat (219.17 egg) than in other insecticides (Table 3).

Table 2- Reproduction parameters (Mean±SE) of Oenopia conglobata contaminata exposed to different insecticides

Parameters	Insecticides	Means±SE
Fecundity (eggs/female)	Control	41.28 [a]± 655.50
	spirotetramat	39.44 [b]± 418.75
	fenitrothion	23.24 [d]± 152.08
	chlorpyrifos	28.69 [c]±240.58
Adult pre-oviposition period (days)	Control	3.66±0.14 [d]
	spirotetramat	4.66±0.50 [c]
	fenitrothion	6.16±0.68 [b]
	chlorpyrifos	7.66±1.67 [a]
Total pre-oviposition period (days)	Control	19.75±0.89 [c]
	spirotetramat	20.75±0.16 [c]
	fenitrothion	21 ±0.09 [b]
	chlorpyrifos	21.83±0.06 [a]

Means±SE; means with different letters are significantly different (the Tukey's test; P< 0.05)

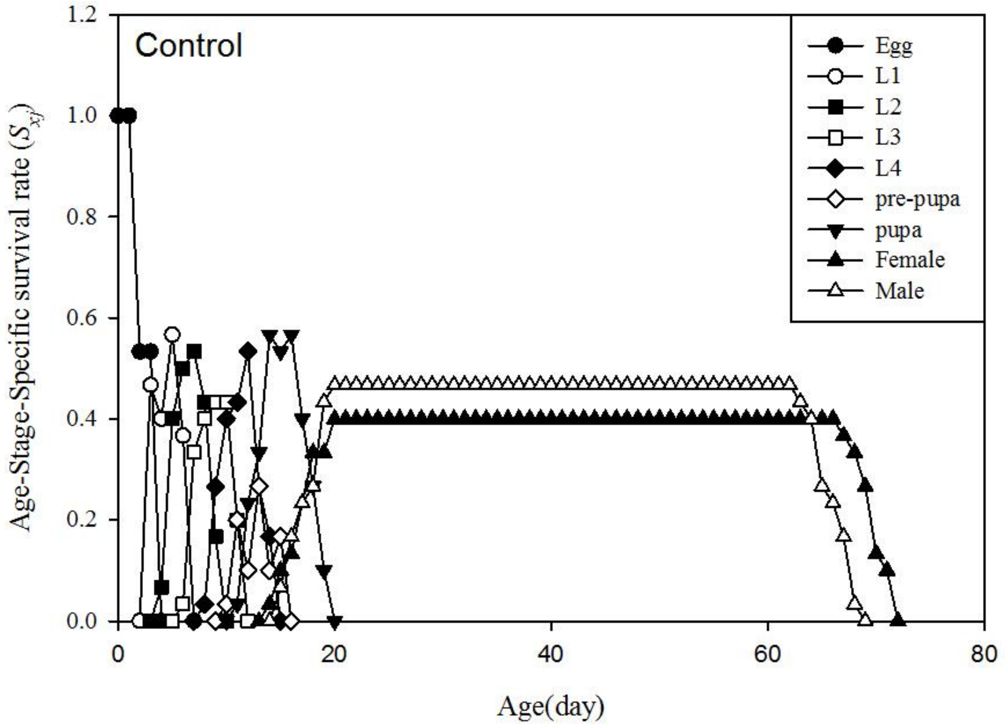
Table 3- Population parameters (Mean±SE) of Oenopia conglobate contaminata exposed to different insecticides

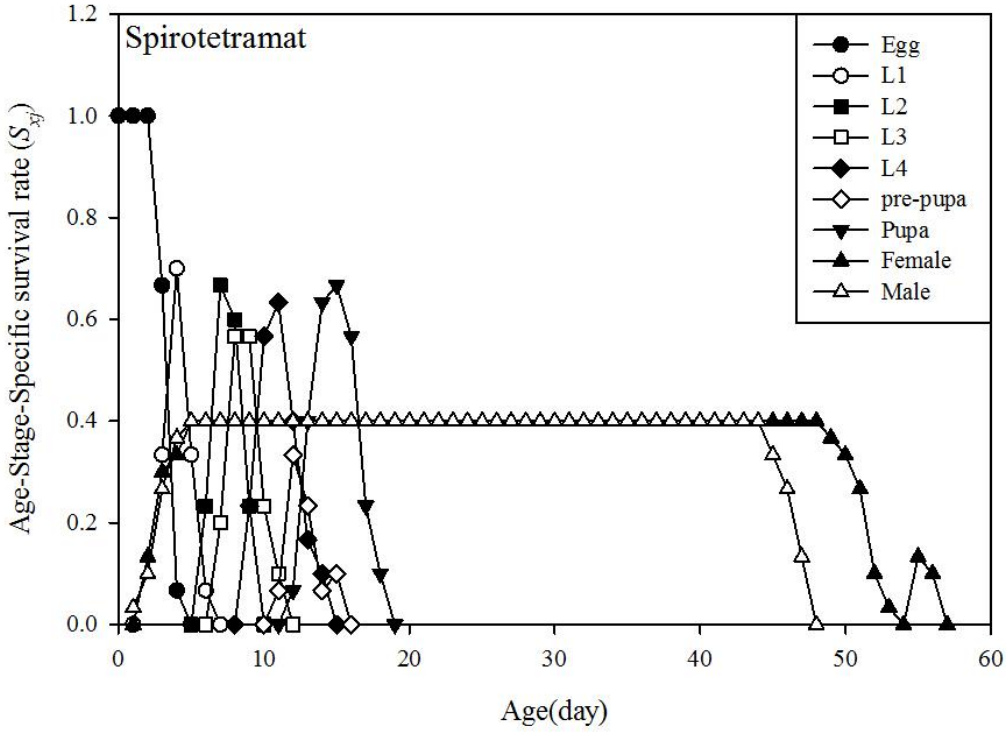
Insecticides	***R*** **(d^{-1})**	***λ*** **(d^{-1})**	***R_0*** **(offspring)**	***T*** **(day)**	***GRR*** **(egg)**
Control	0.18±0.01 [a]	1.19±1.38 [a]	262.0±50.59 [a]	30.70±0.16 [b]	304.33±45.03 [a]
Spirotetramat	0.15±0.00 [b]	1.17±0.00 [b]	167.50±40.58 [b]	32.06±0.17 [a]	219.17±27.77 [b]
Fenitrothion	0.13±0.00 [d]	1.14±0.00 [d]	60.83±15.82 [d]	30.03±0.07 [c]	82.01±19.14 [d]
Chlorpyrifos	0.15±0.01 [c]	1.16±0.00 [c]	96.23±24.49 [c]	29.85±0.09 [d]	153.04±31.26 [c]

Means± SE; means within a column followed by different letters are significantly different ($P< 0.05$; the paired bootstrap test)

The age-stage specific survival curve (S_{xj}) indicates an overlap in variability of the developmental rate and the probability of each stage having survived to age *x* and developed to stage *j*. Accordingly, the survival rate decreased with an increase in the age of *O. conglobata contaminata*. Besides, female adults emerged earlier than male adults and had a longer lifespan. In addition, *O. conglobata contaminata* was able to complete the developmental stage with all three treatments. The probability of newborn eggs of *O. conglobata contaminata* to survive to female adults was approximately 40% for all treatments and the control (Fig. 1).

The l_x, m_x, and l_xm_x of *O. Conglobata contaminata* treated with different insecticides are plotted in Fig. 2. The l_x curve is a simplified version of S_{xj} that ignores differences in the developmental rate among individuals. In all treatments, during the earlier stage of larvae, the l_x curve declined sharply indicating that a higher mortality rate occurred in lower larval instars. Besides, m_x is calculated based on fecundity of the surviving females. Thus, at older ages, because of the low survival rate a few females have less contributing to the population. The highest age-specific fecundity (m_x) was 13.96 offspring in the control, which was calculated to be 8.92, 7.78, and 7.62 in spirotetramat, fenitrothion, and chlorpyrifos, respectively. Besides, the highest fecundity for all tested insecticides was observed in females treated with spirotetramat.


Control
Egg
L1
L2
L3
L4
pre-pupa
pupa
Female
Male
Age-Stage-Specific survival rate (S_{xj})
Age(day)


Spirotetramat
Egg
L1
L2
L3
L4
pre-pupa
Pupa
Female
Male
Age-Stage-Specific survival rate (S_{xj})
Age(day)

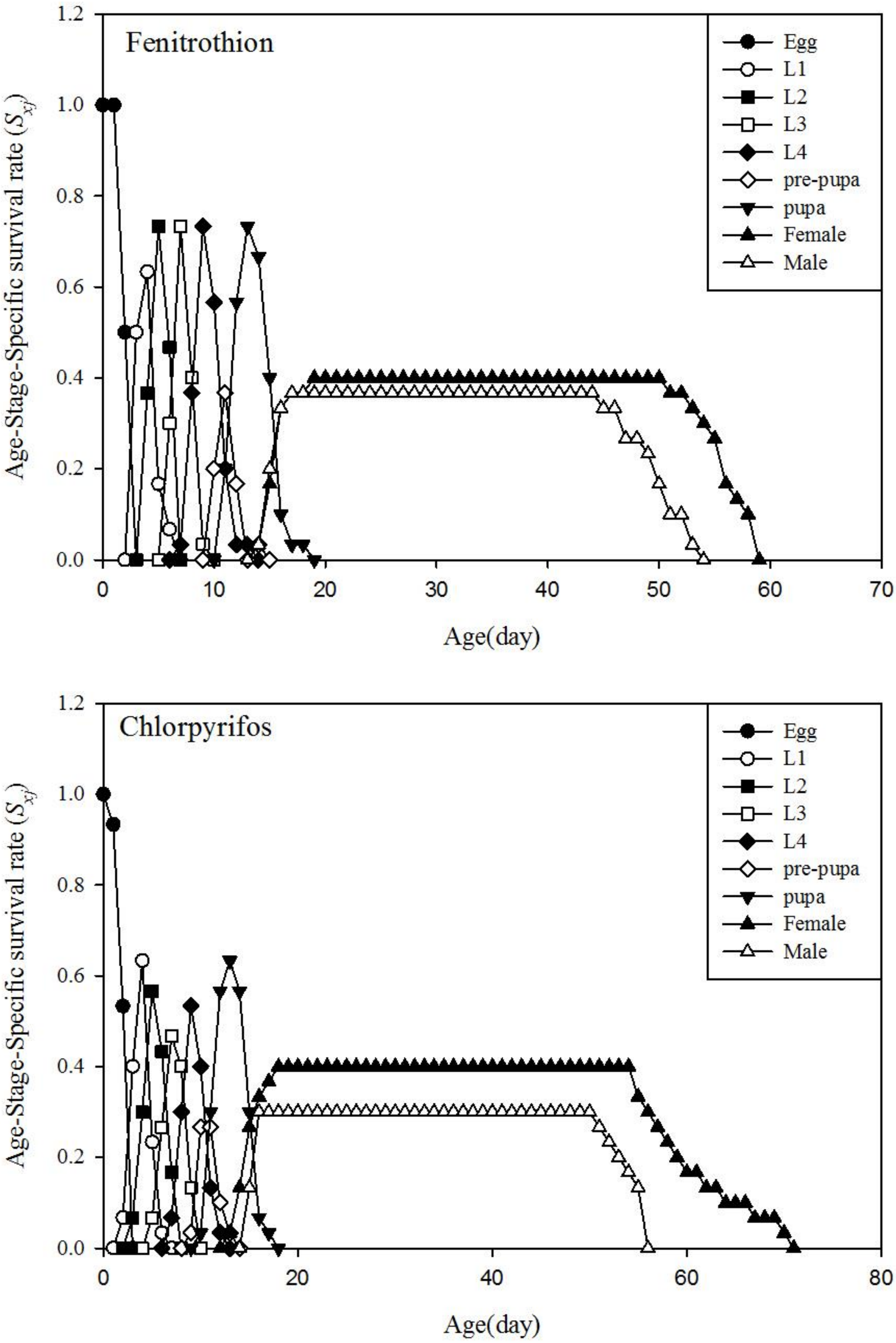
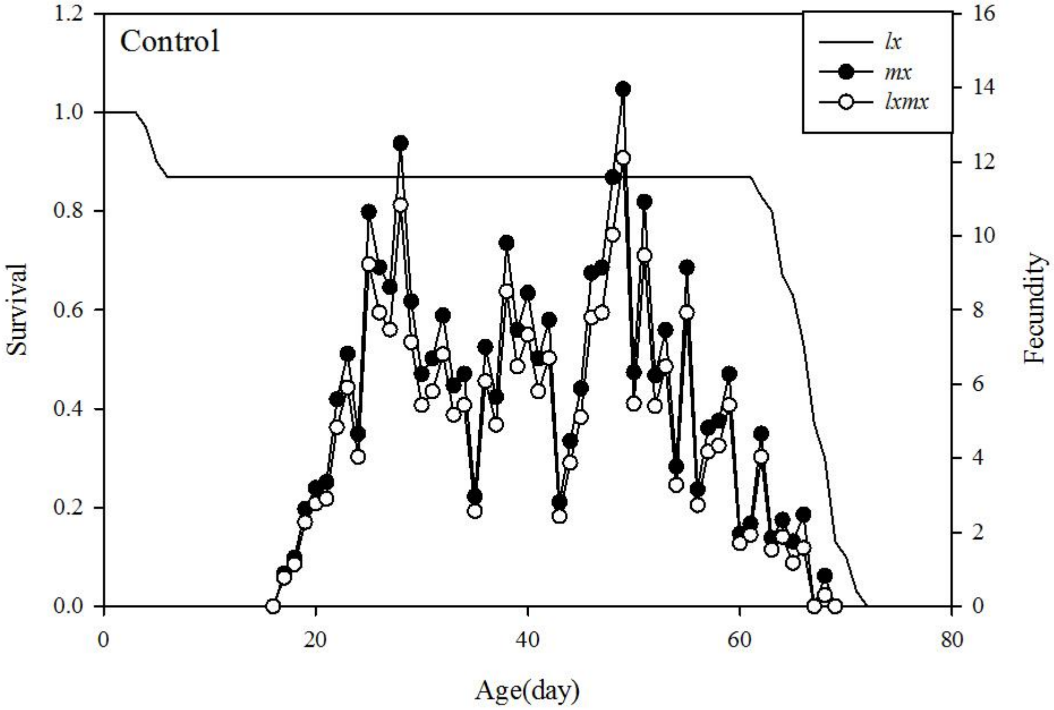


Fig. 1- Age stage-specific survival rate (S_{xj}) of *O. conglobata contaminata* as affected by different treatments


Control
lx
mx
lxmx
Survival
Fecundity
Age(day)
0.0
0.2
0.4
0.6
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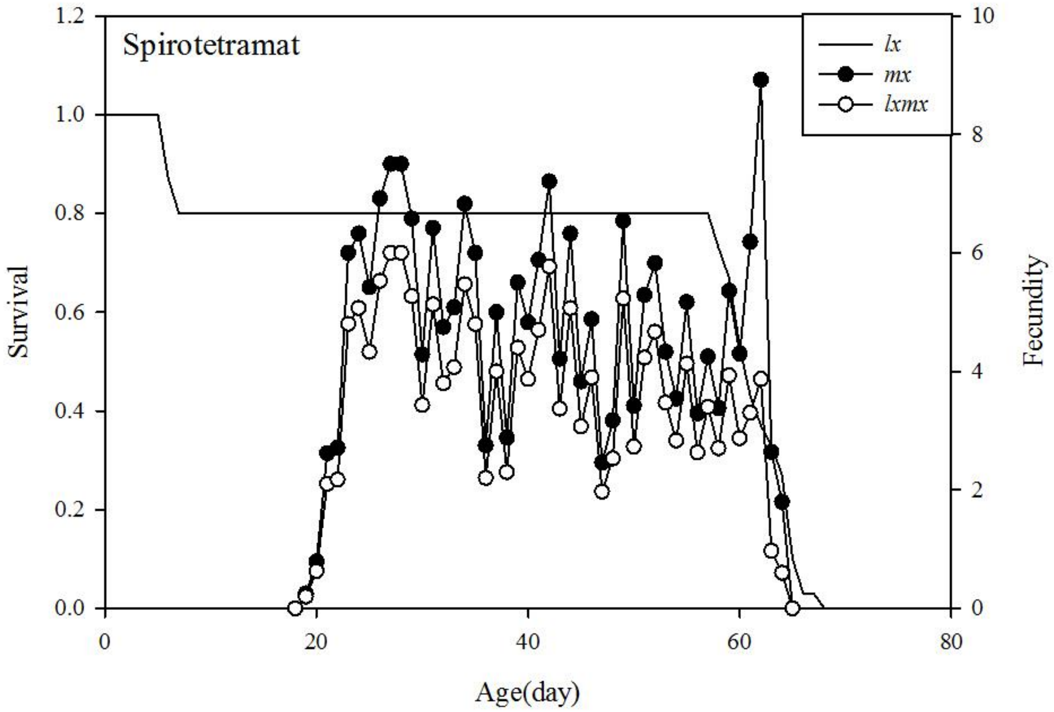
1.2
0
2
4
6
8
10
12
14
16
0
20
40
60
80


Spirotetramat
lx
mx
lxmx
Survival
Fecundity
Age(day)
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2
4
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0
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60
80

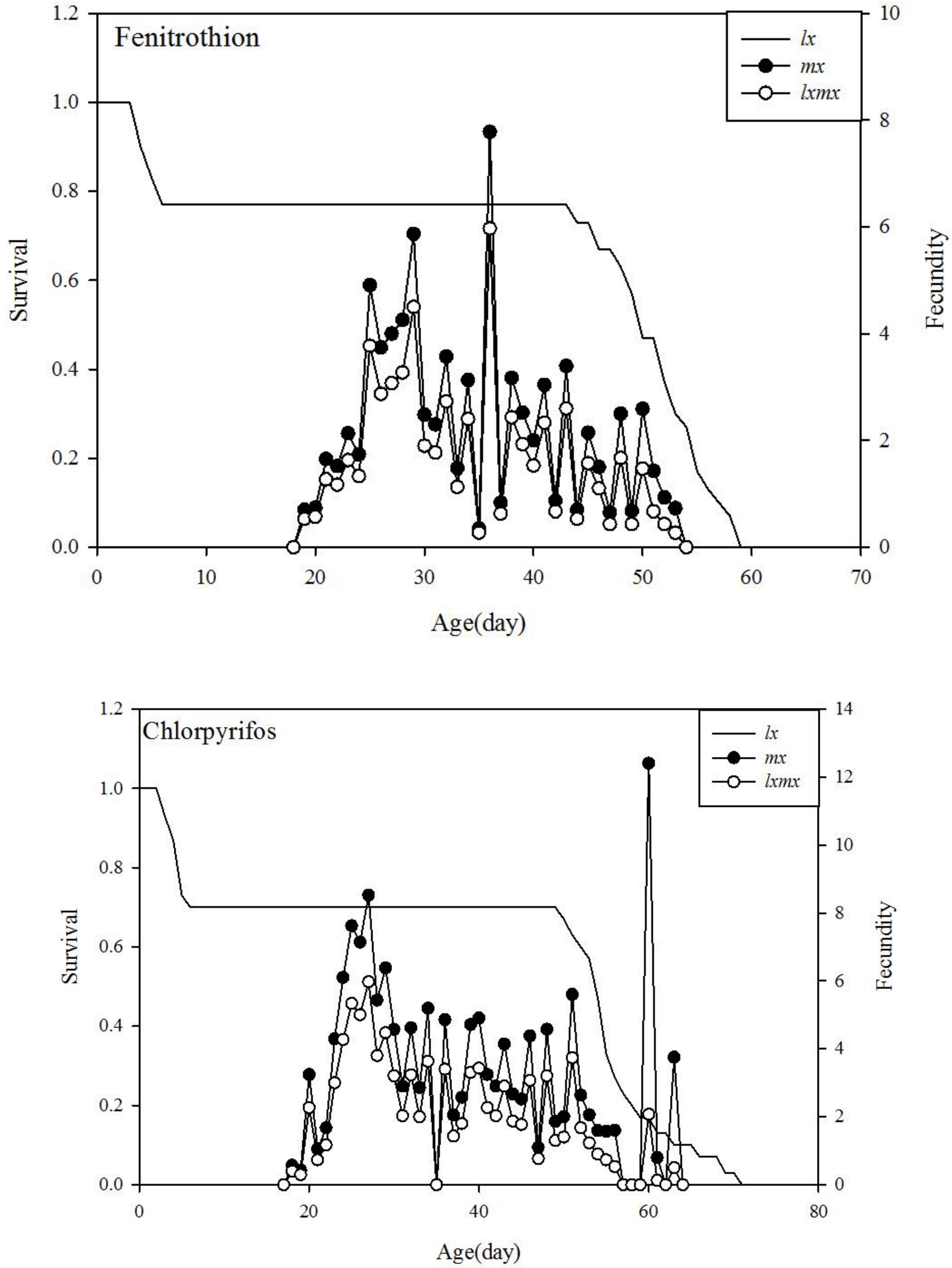

Fig. 2- Age-specific survival rate (*lx*), age-specific fecundity (*mx*), and age-specific maternity (*lxmx*) of *O. conglobata* as affected by different treatments

Life expectancy (e_{xj}) is the time during which an individual of age *x* and stage *j* is expected to live. Accordingly, values of e_{01} (freshly hatched eggs) were 58.8, 51.17, 41.2, and 41.47 days for the control, spirotetramat, fenitrothion, and chlorpyrifos, respectively, which represent mean longevity of all individuals used in the life-table study. In fact, life expectancy of all individuals decreased with an increase in age.

The age stage reproductive value (v_{xj}) describes the contribution of an individual of *O. conglobata contaminata* of age *x* and stage *j* to the future population. Accordingly, v_{xj} increased gradually with an increase in age and stage, and v_{xj} of the females increased significantly when they started ovipositing. Highest reproductive values for the control and other treatments were obtained on days 24, 27, 25, and 23, respectively, with the greatest contribution to the population growth rate made by females.

4. Discussion

Coccinellid predator *O. conglobata* contamination is associated with *A. pistaciae* in pistachio orchards [11]. In this research, coccinellid *O. conglobata contaminata* became exposed to three insecticides commonly used in pistachio orchards. The results presented here are based on sublethal effects (fecundity, eggs, as well as larval and pupal development) on *O. conglobata contaminata* when the insecticides were applied directly. The tetramic acid derivative insecticide, i.e. spirotetramat, acts as a lipid biosynthesis inhibitor [13]. Although it is applied in several areas to different crops, information about its side effects on coccinellids is still scarce [25]. A few studies have reported that this lipid biosynthesis inhibitor is harmless to other predators, such as the coccinellid predator *C. montrouzieri* [16].

Spirotetramat, among the three compounds examined, had the least significant effect on the eggs and larval development time of *O. conglobata contaminata*. Spirotetramat shows some ovicidal activity through direct contact with the eggs of *O. insidious* [17]. In the current study, the developmental time of the larval stage of *O. conglobata contaminata* decreased significantly in fenitrothion and chlorpyrifos treatments, which indicated that spirotetramat had a no adverse effects on the larval stage. Thus, it indicates that spirotetramat could be employed to ensure sustainable use in the IPM program of *A. pistaciae*. Some studies indicate that spirotetramat, in residual contact tests on larvae of *Coccinella septempunctata* L. (Col.: Coccinellidae), exerts less lethality effects on the larval stage [26]. In another study, side effects of *Adalia bipunctata* (Col.; Coccinellidae) treated with four insecticides were examined under laboratory conditions by Depalo *et al* [27]. Accordingly, the results indicated that spirotetramat had a low impact on larval and adult survival. However, in the present study on all insecticides tested, larval mortality had the highest rate in lower larval stages, indicating that these stages are most sensitive to chemical compounds; this implies that adulthood is the ideal stage for being used in an IPM program. In the same vein, Planes *el al* [16] investigated sub-lethal effects of spirotetramat and chlorpyrifos on *C. montrouzieri*. In their study, they reported that spirotetramat had no significant effects on longevity, fecundity, and fertility of *C. montrouzieri*; besides, they concluded that spirotetramat could be compatible with this predator. In recent decades, the use of organophosphate insecticides has disrupted activities of natural enemies. Organophosphate insecticides are the most widely used insecticides in the world. The use of broad-spectrum insecticides exerts many adverse effects on natural enemies [28], including a reduction in survival [29], fecundity, and the population growth rate [30]. Chlorpyrifos, being an organophosphate insecticide, could affect the survival and developmental time of eggs as well as fourth instar larvae of *C. montrouzieri* [14]. This finding was consistent with the current study that found a significant negative effect on different immature stages of *O. conglobata contaminata*. Fenitrothion is a contact-activated organophosphate pesticide and an acetylcholinesterase inhibitor that disrupts the nervous system. In addition, it has a significant effect on larval and adult stages of natural enemies. This organophosphate insecticide caused high mortality in larval and adult stages of *Coleomegilla quadrifasciata* (Col.: Coccinellidae) in peach orchards [15].

Estimation of demographic parameters as well as life table analysis are required for investigation of insect population dynamics; besides, they are required for predicting the population growth rate and comparison of pesticide effects on pest populations and natural enemies in a given climate [7]. The age of first reproduction in females has a significant effect on population growth, so it is important according to demographic parameters of TPOP [31]. In this study, the spirotetramat treatment had no effect on TPOP (20.75 days); therefore, in case of the similarity of the oviposition rate, the shorter pre-oviposition period indicates a higher intrinsic rate of increase (*r*) [32]. In contrast, APOP increased significantly in the spirotetramat treatment compared to other treatments. Besides, sublethal effects of spirotetramat on *cheilomenes sexmaculata* Fabricius (Col.: Coccinellidae) indicated a significant increase in the adulthood pre-oviposition period and fecundity [33]. The intrinsic rate of increase (*r*) is an effective parameter in comparing populations of different species [31-34]. The intrinsic rate of increase of *O. conglobata contaminate*, in the current study, was the highest in the spirotetramat treatment among other treatments. *GRR* is the summation of m_x at the beginning of the reproduction stage, which is calculated based on fecundity of all surviving females. In the spirotetramat treatment, *GRR* was significantly different from other treatments. According to age stage-specific survival rates (S_{xj}), the survival rate in male adults was higher than that in female adults in the control. In chlorpyrifos and spirotetramat treatments, the survival rate of male adults decreased, yet there was no reduction in the survival rate of male adults in the fenitrothion treatment. In general, the results showed that the use of the three different pesticides had no effects on the survival rate of female adults. A number of studies have shown that chlorpyrifos has no effects on the survival rate of female adults of *Chilocorus cacti* (L.) (Col.: Coccinellidae), and fenitrothion has been shown to decrease the survival rate of coccinellid in country bean field [18- 19]. Ideally, novel applications in the modern agriculture should exert no effect on natural enemies of pests and must be compatible with IPM systems [35].

5. Conclusion

In the present study, based on the decrease in the development time to adulthood and increased female fecundity, spirotetramat turned to be the most compatible insecticide. The findings of this study suggest that the use of organophosphates against *O. conglobata contaminata* could not be safe in IPM programs. This study also demonstrated that the use of spirotetramat could fit to augmentative releases of *O. conglobata contaminata*, yet it might reduce effectiveness of this biological control agent through the effects of sublethal residues on the developmental time, intrinsic rate of increase, and fecundity. In contrast, fenitrothion and chlorpyrifos, due to their strong sub-lethal effects, do not seem to be suitable for *O. conglobata contaminata*

Conflict of Interest

The authors confirm that there are no conflict of interests regarding the publication of this study, and that there has been no substantial financial support for this study to have influenced its outcomes.

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