A Study on the Toxicity and Sublethal Concentrations of Three Insecticides on the Population Dynamics of Green Lacewing *Chrysoperla carnea* Stephens

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Abstract

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The study was carried out to evaluate toxicity and sublethal effects of lufenuron, novaluron, and lambda-cyhalothrin on natural enemies such as *Chrysoperla carnea*. All sub-lethal concentrations caused a significant decrease in oviposition period, total fecundity, longevity, and total life span of *C. carnea* compared to the control. Maximum and minimum mean lifespan of *C. carnea* individuals were observed in the untreated group and LC_{30} concentration of novaluron. Total fecundity varied from 153.47 offspring/individual in treatment with LC_{30} novaluron to 300.12 offspring/individual in the control treatment. The highest value for intrinsic and finite rate of increase (r, λ) was obtained by the concentration of lambda-cyhalothrin. The net reproduction rate (R_0) reached its lowest level in novaluron treatment. As a result, the effects of sublethal concentrations of lufenuron, novaluron, and lambda-cyhalothrin on *C. carnea* were assessed and discussed to design improved integrated management programs.

Keywords: Integrated pest management, side effects, aphidophagous predators, natural enemies.

Introduction

The effect of pesticides on the environment, beneficial arthropods, and human health due to exposure to these chemicals are of growing concern, including re-emergence of pests, resistance to pesticides (Maia *et al.*, 2016), environmental pollution (Frank *et al.*, 1990) and emergence of secondary pests (Xu *et al.*, 2008), which led to pests re-emergence as well as natural enemies biodiversity loss (Antonious & Snyder 2006; Osborne & Oetting 1989). The compatibility of pesticides with biocontrol agents is one of the important issues in plant pest management (Stark *et al.*, 2007). Existing insecticides are not always compatible with natural enemies and in some cases lead to resistance in the target pest and the emergence of secondary pests (Amarasekare & Shearer, 2013). Compatibility of pesticides in concomitant use with biocontrol agents is one of the major concerns of users of integrated pest management (IPM) and it is important to have sufficient knowledge about the activity of insecticides against pests, non-target insects, and the environment (Stark *et al.*, 2004). Therefore, understanding the impact of pesticides on beneficial arthropods is essential for the successful integration of biocontrol in agricultural ecosystems (Croft, 1990).

The presence of natural enemies as biocontrol agents has a special place in integrated pest management programs due to reducing the damage caused by the presence of key pests and preventing the outbreak of secondary pests (Saber *et al.*, 2018). One of the most important types of lacewing predators, the Chrysopidae family is one of the most important and effective predators in greenhouses, orchards, and agricultural fields, to control insects such as aphids, weevils, caterpillars, whiteflies and psyllids (Fathipour & Jafari, 2004). Among the species belonging to this family, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) is a polyphagous predator, which is an important component due to its wide geographical distribution, high adaptation to different environmental conditions, and its considerable potential in feeding on several species of pests (Jones *et al.*, 2011; Horton *et al.*, 2009; Mansfield & Mills 2002; Zeb Khan *et al.*, 2015). In addition, the high resistance of green cultivars to a large number of common pesticides has increasingly highlighted the importance of this beneficial insect in integrated pest control programs (Khan Pathan *et al.*, 2008).

Today, integrated pest management strategies, such as combining biocontrol agents with industrial pesticides, are used by a large number of crop growers around the world (Calvo *et al.*, 2011). To achieve this, in addition to evaluating the lethal effects of different concentrations of pesticides, the study of sub-lethal concentrations should also be considered. One of the methods used to protect natural enemies and manage early resistance is the use of sublethal concentrations (He *et al.*, 2013; Song *et al.*, 2013). The effects of sublethal concentrations of pesticides can affect the pest population and play a good role in control (Stark & Banks, 2003).

Evaluating the effects of pesticides in vitro to obtain information about how they have potential effects on arthropods can be important and useful (Havasi *et al.*, 2019). On the other hand, the importance of using the life table method and demographic studies as a safe and reliable method in determining competency (Chi *et al.*, 2020),

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determining the toxicity of pesticides (Chi, 1990), evaluating the side effects of pesticides on the population growth rate, and fertility (Li *et al.*, 2017) and a study of pest populations (Kakde *et al.*, 2014, Sakai *et al.*, 2001;), has been raised.

Because green lacewing is one of the most effective and useful general pest hunters in various crops and greenhouses, and due to the high consumption of insecticides such as lufenuron, novaluron, and lambda-cyhalothrin in various commercial products, it was recommended to study the lethal and sub-lethal effects of these chemical compounds on this widely used biocontrol agent to achieve the most suitable application approach. Furthermore, it was necessary to evaluate the insecticidal effects of these compounds on the demographic parameters of the green lacewing using the age-stage two-sex life table theory to determine the effectiveness of the most suitable chemical compound to be used in integrated management programs.

Materials and Methods

Ephestia kuehniella

A colony of the Mediterranean flour moth, *Ephestia kuehniella* Zell (Lepidoptera: Pyralidae) adults (for the rearing of *C. carnea*) were provided by the Iranian Research Institute of Plant Protection (IRIPP), and was reared in a big plastic container with a net cloth (70 cm in diameter × 25 cm high). In each dish, a layer of mixed wheat flour and wheat bran plus wheat yeast (2.5:0.5:40; kg:kg:g) was added, and then one gram of *E. kuehniella* eggs was spread uniformly on it. The plastic containers were kept under controlled conditions of 25±2°C, 60±5 % RH, and a photoperiod of 16:8 h (Dark:Light). After oviposition of adults, the eggs were collected and refrigerated (4°C) for as long as they were required to feed the green lacewing.

C. carnea

The initial colony of green lacewing, *C. carnea*, and adults were provided by the Iranian Research Institute of Plant Protection (IRIPP). Based on Golmohammadi *et al.* (2021b), *C. carnea* was reared in a plastic cylinder container, covered with a net cloth. The adults were fed on an artificial diet containing yeast, honey, and distilled water (4:7:5 g/g/ml), and their larvae were fed with eggs of *E. kuehniella*, daily. To prevent cannibalism in the colony, the larvae were placed in containers with a soft cloth layer, and larvae were positioned between these layers. Each layer had 15 larvae of *C. carnea* and enough eggs of *E. kuehniella*. After the emergence of pupae, they were collected and transferred to another container. Rearing containers were maintained at 25±2C°, 60±5% RH, and a photoperiod of 16:8 h (Light: Dark).

Insecticides

The insecticides used were the commercial product (Match®) containing 50 g/L lufenuron formulated as a concentrated emulsion (Syngenta Crop Protection Ltd.), novaluron (Rimon 0.83 EC, Chemtura AgroSolutions, Middlebury, CT) 363.4 g (ai)/ha, lambda-cyhalothrin (Warrior II CS, Syngenta LLC Inc., Greensboro, NC) 46.6 g (ai)/ha.

Bioassay experiments

To assess the sublethal effects of selected insecticides, adult males and females of same age *C. carnea* (< one day old) of the same age was used for bioassay experiments. Their sex was identified under stereo microscopy according to the shape of the sternite at the end of the abdomen (Vafaie *et al.*, 2019). Bioassays using contact toxicity (Mohammadi *et al.*, 2009) in plastic Petri dishes (6 cm in diameter and 1 cm high) under a temperature of 25±2°C, relative humidity of 65±5%, and photoperiod of 16:8 hours (dark:light) were used. Primary experiments were first performed to determine 10-90% mortality in adult insects (Robertson *et al.*, 2007). Then using logarithmic distances, five concentrations in distilled water including 100, 130, 150, 180, and 205 ppm for novaluron; 70, 85, 110, 165, and 1850 ppm for lufenuron and 30, 45, 65, 80, and 105 ppm for lambda-cyhalothrin were used. Distilled water was also used for the control treatment. After preparing the concentrations, the first 2 ml of each concentration was poured on two surfaces of Petri dishes with a diameter of 10 cm (each level, one ml) and kept at room temperature for thirty minutes until their surface was completely dry. Then 10 pairs of male and female insects (10:10) were placed separately in each container. Petri dishes were then transferred to controlled conditions in an incubator with a temperature of 25±2°C, relative humidity of 65±5%, and a photoperiod of 8:16 h (light:dark), and after 24 h later the dead male and female insects were counted separately untill the end of the experiment. The main experiments were performed at 5 concentrations and 4 replications.

Life-table assay

To evaluate the sublethal effects of lufenuron, novaluron, and lambda-cyhalothrin on the parameters of the green lacewing with the LC_{30} concentration of each insecticide was estimated (Table 1). After preparing the concentrations, 100 pairs of both male and female insects with an age of fewer than 24 hours were selected for treatment with each insecticide. Distilled water was used for the control treatment. 24 hours after treatment with insecticides, the treated adults who survived were selected for the next experiment. Then 20 pairs (10:10, male: female) of adult insects were transferred to containers with an opening diameter of 8 cm (height 16 cm) for spawning. On the wall of each glass, a plastic talcum tape was glued to the outer wall of the glass so that on the days of insect spawning, pre-prepared food (yeast, water, and honey, 5:7:4; g:g:ml) (Golmohammadi & Hejazi, 2014) was placed on these strips. The tops of these glasses were covered with a lace cloth and a small piece of sponge on these nets to supply the water needed by the insect (Golmohammadi & Hejazi 2014). The dishes were changed daily when the adults started spawning and the eggs laid in each dish were counted daily. At the end, all experiments were conducted in a growth chamber at 25±2℃, 65±5% RH, and a photoperiod of 16:8 (L:D) hours photoperiod. The survival, development time, oviposition period, and fecundity, as well as the population parameters of both sexes, were determined until death of the last sample.

Statistical analysis

To determine the lethal and sublethal concentrations (LC_{90}, $LC_{50,}$ and LC_{30}), the concentration-mortality regression of biocontrol agents were obtained using a Probit program of the IBM SPSS-version 19.0 (IBM SPSS, 2010). The raw life history data were analyzed based on age stage, a two-sex life table (Chi & Liu 1985; Chi 1988), using the software TWO SEX MSChart program (2021 version) (Chi, 2021) The variances and standard errors of the population growth parameters were estimated by the bootstrap procedure (Efron & Tibshirani 1994). Furthermore, the paired bootstrap (×100,000) test was applied for the statistical differences among the means of parameters related to development, fecundity, as well as population parameters (population growth parameters including the gross reproductive rate (*GRR*), net reproductive rate (R_0), intrinsic rate of increase (*r*), finite rate of increase (λ), mean generation time (*T*) of different treatments (Efron & Tibshirani, 1994; Huang & Chi 2013).

Results

Concentration-response bioassay

The category and toxicity of tested insecticides on the green lacewing *C. carnea* are summarized in Table 1. The LC_{30} of novaluron was less than that of lufenuron and lambda-cyhalothrin (Table 1). Results also revealed that there was a significant difference between LC_{50} and LC_{30} of the insecticides. However, LC_{90} of novaluron and lufenuron was not statistically significantly different (Table 1).

Development time, longevity, and total life span

The results obtained showed a significant effect between males and females after the exposure of *C. carnea* to sublethal concentrations of lufenuron, novaluron, and lambda-cyhalothrin during the developmental time compared with those in the control treatment. In addition, the sublethal concentrations of LC_{30} resulted in a significant reduction in adult longevity and total lifespan of both males and females compared with the control treatment. The longest and shortest female adult longevity (longest: 42.98 days for control; shortest: 27.90 days for lambda-cyhalothrin LC_{30}), as well as total life span (longest: 67.25 days for control; shortest: 51.57 days for lufenuron LC_{30}), were observed in control and LC_{30} lambda-cyhalothrin and lufenuron treatment, respectively (Table 2).

Reproductive Periods

The highest fecundity of *C. carnea* of 300.12 eggs/female was observed in the control (Table 3). Conversely, LC_{30} concentration of novaluron resulted in the lowest fecundity. The females treated with LC_{30} of lufenuron, novaluron, and control, had no significant difference on adult pre-oviposition periods (APOP= the duration from female emergence to first oviposition) compared to the control. The maximal oviposition period of *C. carnea* was observed in the control, reaching a maximum of 33.27 days. This parameter significantly decreased in response to LC_{30} concentrations from lambda-cyhalothrin to lufenuron and novaluron (ranging from 30.73 to 25.02 days). The mean number of eggs per female was affected by sublethal concentrations, and it showed a declining trend when exposed to lufenuron and novaluron (Table 3).

Table 1. Probit analysis for the concentration-mortality response of adult stage of *Chrysoperla carnea* to lufenuron, novaluron, and lambda-cyhalothrin insecticides.

Insecticide	N*	LC_{30} (ml/L) (95% CL°)	LC_{50} (ml/L) (95% CL)	LC_{90} (ml/L) (95% CL)	*df*	Slope ± SE	χ^2
Lufenuron	480	90.3 b (84-96)	115.8 b (109.6122.4)	212.3 a (192.9-240.9)	4	4.86 ± 0.45	10.70
Novaluron	480	128.1 a (122.0-133.3)	150.2 a (144.9-155.6)	221.4 a (208.3-240.0)	4	7.59 ± 0.72	4.48
Lambda-cyhalothrin	480	46.7 (43-50)	61.3 c (57.6-65.1)	118.6 b (106.9-135.8)	4	4.46 ± 0.42	10.34

*20 individuals per replicate, four replicates per concentration, six concentrations per assay.
CL= Confidence Limit

Table 2. Means (±SE) of the growth duration and survival of *Chrysoperla carnea* treated with sub-lethal concentration (LC_{30}) of the insecticides lufenuron, novaluron, and lambda-cyhalothrin in comparison with the control.

Parameters	Sex	Control	Lufenuron	Novaluron	lambda-cyhalothrin
Developmental time (day)	Male	21.01±0.39 b	20.81±0.16 b	20.56±0.51 b	22.25±0.51 a
	Female	24.27±0.29 a	20.43±0.26 c	22.48±0.27 b	22.15±0.24 b
Longevity (day)	Male	42.12±1.55 a	27.85±1.55 c	28.83±1.38 c	33.77±2.16 b
	Female	42.98±2.27 a	31.13±3.23 b	29.23±2.45 b	27.90±0.95 c
Total life span (day)	Male	63.11±1.78 a	48.65±1.53 b	49.39±1.47 b	50.15±1.18 b
	Female	67.25±2.34 a	51.57±3.21 c	51.72±2.39 c	55.92±2.16 b

The standard errors were calculated using the bootstrap procedure with 100,000 samples. Means followed by different letters in the same row are significantly different using the paired bootstrap test at P=0.05.

Population growth parameters

The *GRR*, R_0, *r*, *λ,* and *T* parameters of *C. carnea* individuals were significantly reduced by all treatments of insecticides (Table 4). However, *r* and *λ* parameters were significantly reduced at LC_{30} of novaluron (Table 4). Furthermore, *T* had a different trend. This parameter declined in LC_{30} treatments for lufenuron. In *C. carnea* individuals, the highest *T* value was obtained for untreated green lacewing (Table 4).

Survival and Fecundity

Age-specific survivorship (l_x) and age-specific fecundity (m_x) of *C. carnea* at different concentrations of lufenuron, novaluron, and lambda-cyhalothrin are shown in Figures 1 and 2. The total lifetime for the untreated green lacewing *C. carnea* was 82 days, 81, 78, and 72 days for lambda-cyhalothrin, lufenuron, and novaluron treatments, respectively (Figure 1). In addition, the maximum values of m_x were approximately 10.54 eggs/female/day for *C. carnea* treated with lambda-cyhalothrin treatment, which was on day 52 of the lifespan (Figure 2). The maximum value of m_x for untreated *C. carnea* was 8.65 eggs/female/day observed on day 55 of the lifespan. However, maximum values of m_x for lufenuron and novaluron treatments were approximately 6.88 and 6.79 eggs/female/day, respectively, which occurred on days 56 and 52 (Figure 2).

Discussion

Achieving effective biocontrol agents is the first step in developing integrated pest management programs (Fathipour *et al.,* 2020). On the other hand, the compatibility of pesticides with natural enemies and plant pests should be assessed to develop strategies related to integrated pest management (Biondi *et al.,* 2012; Desneux *et al.,* 2006). Evaluation of the toxic effects of pesticides against natural enemies is also important and necessary in the development of pest management (Desneux *et al.,* 2007; Golmohammadi & Hejazi, 2014).

The lethal effects of pesticides refer only to a partial measurement of their adverse effects, which obscures other dimensions of the pesticides effect, such as the sub-lethal effects on the physiology and behaviour of arthropods (Desneux *et al.,* 2007). The sub-lethal effects can be very sensitive and affect populations at concentrations below the concentration-loss curve (Stark & Banks, 2003). Several previous studies have examined the sub-lethal effects of different insecticides on the biological parameters of *C. carnea* (Garzón *et al.,* 2015; Maia *et al.,* 2016; Mohammadi *et al.,* 2009; Suárez-López *et al.,* 2020).

Table 3. Insecticidal effect of lufenuron, novaluron, and lambda-cyhalothrin on some biological characteristics (Means ±SE) of *Chrysoperla carnea* compared to control.

Parameter	Control	Lufenuron	Novaluron	Lambda-cyhalothrin
Oviposition (day)	33.27±2.13 a	26.17±3.03 c	25.02±2.44 c	30.73±2.07 b
APOP (day)	3.42±0.16 a	3.97±0.07 a	3.85±0.16 a	1.81±0.18 b
TPOP (day)	27.70±0.33 a	24.41±0.26 b	26.32±0.31 a	23.95±0.26 b
Total Fecundity (offspring/female)	300.12±19.37 a	183.77±23.20 c	153.47±18.16 d	238.38±19.44 b

The standard errors were calculated using the bootstrap procedure with 100,000 samples. Means followed by different letters in the same row are significantly different using the paired bootstrap test at p=0.05. APOP= adult pre-oviposition period (the duration from adult emergence to the first oviposition); TPOP= total pre-oviposition period (the duration from egg to the first oviposition).

Table 4. Population growth parameters (Mean ± SE) of *Chrysoperla carnea* under the influence of sub-lethal concentration (LC_{30}) of the insecticides lufenuron, novaluron, and lambda-cyhalothrin in comparison with the control.

population parameters	Control	Lufenuron	Novaluron	Lambda-cyhalothrin	Unit
Gross reproduction rate (*GRR*)	302.60±20.52 a	214.05±22.76 c	195.87±17.14 d	279.51±24.96 b	offspring/individua/ Generation
Net reproductive rate (R_0)	240.10±22.87 a	110.26±18.70 c	105.84±15.48 c	158.91±19.31 b	offspring/individua/ Generation
Intrinsic rate of increase (*r*)	0.129±0.002 b	0.128±0.004 b	0.120±0.003 c	0.137±0.003 a	Day^{-1}
Finite rate of increase (*λ*)	1.138±0.002 b	1.137±0.004 b	1.128±0.004 c	1.147±0.003 a	Day^{-1}
Mean generation time (*T*)	42.26±0.52 a	36.57±0.67 c	38.55±0.58 b	36.91±0.50 c	Day

Means in the same row followed by the same letters are not significantly different at P=0.05. The SE were estimated by using 100,000× bootstraps and compared by using paired bootstrap test at 5% significance level.

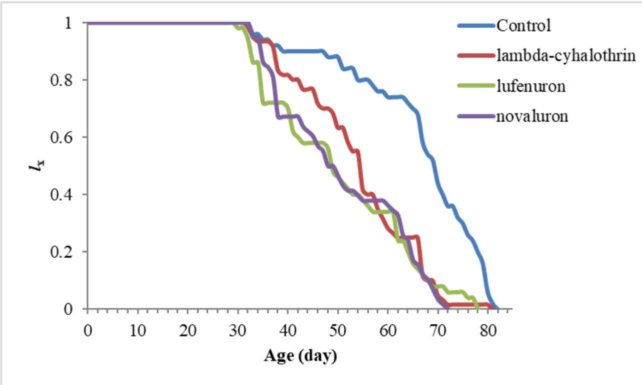

Figure 1. Age-specific survivorship (l_x) of offspring of *Chrysoperla carnea* treated with a sublethal concentration of lufenuron, novaluron, and lambda-cyhalothrin.

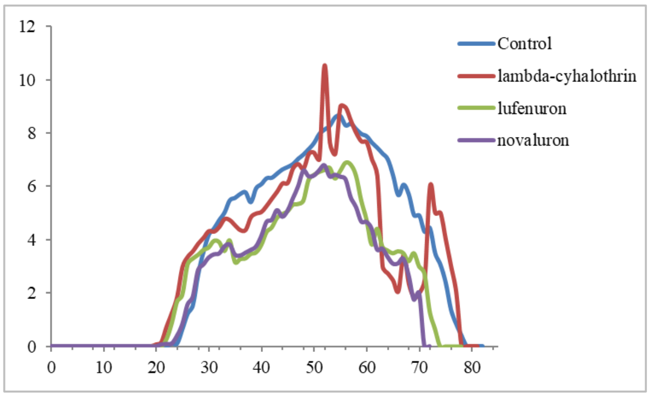

Figure 2. Age-specific fecundity (m_x) of the offspring of the treated and untreated *Chrysoperla carnea* by the sublethal concentrations of lufenuron, novaluron, and lambda-cyhalothrin.

The use of imidacloprid (neonicotinoid), thiaclopride (neonicotinoid), and lambda c-halotrine (pyrithroid) insecticides caused a statistically significant decrease in the average adult *Adalia bipunctata* L. (Coleoptera) survival (Skouras *et al.,* 2021), and adults of *C. carnea* had a significant reduction in survival after treatment with the insecticide thiamtoxam (Gontijo *et al.,* 2014). When *A. bipunctata* adults were exposed to the insecticides sulfoxafluoride and deltamethrin, their survival and productivity were significantly reduced (Garzón *et al.,* 2015). In another study, it was reported that the use of thiamtoxam reduced the effect on the earlier stages of *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae), which is consistent with the data obtained in this study for females treated with lufenuron, novaluron, and lambda-cyhalothrin insecticides (Sâmia *et al.*, 2019).

In another study, it was reported that the use of lufenuron reduces the duration of developmental time in males and females of green lacewing, which is consistent with the findings of the present study (Suárez-López *et al.,* 2020). Less susceptibility of *C. carnea* larvae was recorded when consuming neem treated aphids compared to *Coccinella septempunctata*. However, consumption of aphids, development period, survival and longevity were all affected significantly (Hussain *et al.*, 2012). The study of the effects of the insecticide thiacloprid on the biological parameters of green lacewing showed that the use of this insecticide reduces the life expectancy of *C. carnea* adults compared to the control treatment, which is consistent with the findings of the present study (Asadi Eeidvand *et al.,* 2015). According to the findings of Ono *et al.* (2017), the application of deflobenzuron and lufenuron on adults of *Ceraeochrysa cuban* (Hagen) (Neuroptera, Chrysopidae) caused a significant reduction during the pre-adult period. Furthermore, in a study conducted by Golmohammadi *et al.* (2021a), it was reported that the sublethal concentration (LC_{30}) of the insecticides clotianidine and flopiradifuran significantly reduced the survival of adult green baltic insects. Mortality of both predators was infuenced by ingestion of contaminated mealybug and least mortality (15%, 35%) was recorded with citrus oil, while maximum mortality (25%, 60%) was reached by profenofos (LC_{25}) compared to control (10%, 30%) for *C. montrouzieri* and *C. carnea*, respectively (Bibi *et al.,* 2021). Wankhade *et al.* (2020) obtained similar results after application of sublethal concentrations of thiamthoxam 0.2 mg, lambda-cyhalothrin 0.6 ml, and thiaclopride 0.18 ml on *Chrysoperla* spp. This research showed that the use of these concentrations significantly reduced the total fertility of *Chrysoperla* spp. A similar situation was observed with a significant reduction in total fertility for indoxacarb (Golmohammadi *et al.*, 2021b) and thiamtoxam and clotianidine (Rahangdale *et al.,* 2017) and imidacloprid (Tesfaye *et al.,* 2005) for the same studied species. Suárez-López *et al.* (2020) showed a significant adverse effect of lufenuron, both by direct contact on larvae and following ingestion by adults. In addition, when *C. carnea* larvae fed on prey treated with lufenuron, which was their preference, high pupal mortality rates obtained. In another study (Medina *et al.,* 2002), the use of deflobenzuron did not produce significantly difference in the fecundity rate of *C. carnea*. Among the possible reasons for these differences are the type and manner of application of the applied insecticide in addition to the differences in experimental conditions. Diflobenzuron is a gastrointestinal contact insecticide of the benzoyl urea group that prevents skin formation and kills insects by inhibiting chitin synthesis in all stages (Grigoraki *et al.,* 2017). Neonicotinoid group insecticides kill pests by disrupting the nervous system and mimicking acetylcholine (Nauen *et al.*, 2003).

Golmohammadi *et al.* (2013), who studied the sub-lethal concentration (LC_{25}) of endosulfan and indoxacarb insecticides on *C. carnea* adults, reported that the application of sublethal concentrations of these insecticides significantly reduced biological parameters such as gross reproduction rate (*GRR*), net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ) in the population of treated people compared to the control. Kim *et al.* (2006) reported in their study that the application of sublethal concentrations of acetaminophen did not have a significant effect on the growth rate of the predatory age of *Deraeocoris brevis* (Uhler), which contradicts the findings of the present study (exempt lambda-cyhalothrin). A similar study by Rugno *et al.* (2019) showed a significant reduction in the net reproductive rate (R_0) for *Ceraeochrysa cubana* (Hagen)

Based on the results obtained in this study, it can be concluded that among the subcutaneous concentrations (LC_{30}) of lufenuron, novaluron and lambda-cyhalothrin insecticides, the insecticide lambda-cyhalothrin had fewer negative effects on biological parameters and population dynamics which makes it a likely component in integrated management programs, especially in areas where biocontrol is performed with the release of *C. carnea*. It is also important to note that to confirm the laboratory results obtained, field experiments to investigate the lethal and sub-lethal effects of the studied insecticides on *C. carnea* need to be investigated.

(Neuroptera: Chrysopidae) treated with imidacloprid which was consistent with the findings of this study. Likewise, and in agreement with the results obtained in this study, Shakoorzadeh *et al.* (2013) who studied the effect of dinotofuran and thiamtoxame insecticides on green Baltura bioremediates, reported that the use of thiamtoxam significantly reduced the net reproductive rate, the finite rate of population increase, the rate of population increase. The population and the mean duration of a generation compared to the control were consistent with the results obtained in this study for lufenuron and novaluron.

الملخص

السندي، أياد، علي عبد الحسين كريم، محمد رضا هفاسي وغلام رضا غلام محمدي. 2023. دراسة حول السميّة والتراكيز شبه المميتة لثلاثة مبيدات على ديناميكية أعداد المفترس أسد المنّ Stephens *Chrysoperla carnea*. مجلة وقاية النبات العربية، 41(1): 28–36.
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أجريت هذه الدراسة لتقييم السمّية والتأثير القاتل للمبيدات lufenuron، novaluron و lambda-cyhalothrin على المفترس أسد المنّ *Chrysoperla carnea*. سبّبت جميع تراكيز الجرعة القاتلة انخفاضاً معنوياً في فترة وضع البيض، والخصوبة، وطول العمر، وإجمالي دورة حياة *C. carnea* مقارنةً مع معاملة الشاهد. تمّت ملاحظة الحدّ الأقصى والحدّ الأدنى لمتوسط عمر أفراد *C. carnea* في المجموعة غير المعاملة وتأثير تركيز LC_{30} من novaluron، حيث تباينت الخصوبة الكلية من 153.47 نسلاً/فرد في المعاملة باستخدام تركيز LC_{30} للمبيد novaluron إلى 300.12 نسلاً/فرد في معاملة الشاهد. تمّ الحصول على أعلى قيمة لمعدل الزيادة الجوهرية والمحدودة (r, λ) في معاملة المبيد lambda-cyhalothrin. بلغ معدل التكاثر الصافي (R0) أدنى مستوىً له في معاملة المبيد novaluron. هدفت نتائج الدراسة إلى تقييم ومناقشة تأثيرات التراكيز شبه المميتة من المبيدات الثلاثة lufenuron، novaluron و lambda-cyhalothrin على المفترس أسد المنّ، وإمكانية استخدامها بشكل آمن لدعم برامج الإدارة المتكاملة للآفات الحشرية.

كلمات مفتاحية: إدارة متكاملة للآفات، أثر جانبي، مفترسات متغذية على المنّ، أعداء طبيعية.

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