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Scientific Article

Residual toxicity of insecticides applied to first-stage lacewing larvae

Toxicidade residual de inseticidas aplicados sobre larvas de crisopídeos de primeiro ínstar

Maurício S. de Godoy[1], Alcimar G. de Lira[1]*, Alricélia G. de Lima[1], Adrian J. Molina-Rugama[1], Patrik L. Pastori[2], Elisângela de S. Loureiro[3], Edson A. da Fonseca Junior[1], Shara C. S. Mesquita[1]

[1]Department of Agricultural and Forestry Sciences, Universidade Federal Rural do Semi-Árido, Mossoró, RN, Brazil. [2]Universidade Federal da Grande Dourados, Dourados, MS, Brazil. [3]Department of Plant Protection, Universidade Federal de Mato Grosso do Sul, Chapadão do Sul, MS, Brazil.

ABSTRACT - Lacewings (Chrysopidae) are predators that regulate mealybug, aphid, whitefly, and lepidopteran populations in various important agricultural crops. The predator *Chrysoperla genanigra* Freitas (Neuroptera: Chrysopidae) is widely found in melon production areas, where various chemical pesticides are usually applied for pest control. Studies evaluating the impact of these pesticides on *C. genanigra* are incipient. Thus, the objective of this study was to assess the residual toxicity of seven insecticides on *C. genanigra* larvae. The experiment was conducted under laboratory conditions at temperature of 25±2 °C, relative humidity of 70±10%, and 12-hour photoperiod. The treatments tested were: azadirachtin, abamectin, cyantraniliprole, thiacloprid, pymetrozine, imidacloprid, novaluron, and distilled water (control). Insecticides were applied at the highest rates recommended by the manufacturers, and their toxicities were categorized using the method recommended by the International Organization for Biological Control (IOBC). All insecticides significantly affected larval mortality, pupation percentage, and adult emergence of the predator *C. genanigra*. Total accumulated mortality ranged from 93% to 100% among the analyzed insecticides; the highest mortality rate was found for first-instar larvae. The seven insecticides were toxicologically classified as Class 4 and, therefore, non-selective to the predator when tested on first-instar larvae of *C. genanigra*. Research under semi-field and field conditions should be conducted to assess the selectivity of the tested insecticides.

Keywords: Plant health. Melon. Pesticides. Natural enemy. *Chrysoperla genanigra.*

RESUMO – Os crisopídeos (Chrysopidae) são predadores que regulam as populações de cochonilhas, pulgões, moscas brancas e lepidópteros em diversas culturas de importância agrícola. O predador *Chrysoperla genanigra* Freitas (Neuroptera: Chrysopidae) é amplamente encontrado em áreas de produção de melão, onde diversos agrotóxicos são normalmente aplicados para o controle de pragas. Estudos que avaliam o impacto desses pesticidas sobre *C. genanigra* são incipientes. Assim, o objetivo deste estudo foi avaliar a toxicidade residual de sete inseticidas sobre larvas de *C. genanigra*. O experimento foi conduzido em condições de laboratório com temperatura de 25±2 °C, umidade relativa de 70±10% e fotoperíodo de 12 horas. Os tratamentos testados foram: azadiractina, abamectina, ciantraniliprole, tiacloprido, pimetrozina, imidacloprido, novaluron e água destilada (controle). Os inseticidas foram aplicados nas maiores dosagens recomendadas pelos fabricantes, e suas toxicidades foram categorizadas usando o método recomendado pela Organização Internacional de Controle Biológico (IOBC). Todos os inseticidas afetaram significativamente a mortalidade larval, a porcentagem de pupação e a emergência de adultos do predador *C. genanigra*. A mortalidade total acumulada variou de 93% a 100% entre os inseticidas analisados; a maior taxa de mortalidade foi encontrada para larvas de primeiro instar. Os sete inseticidas foram classificados toxicologicamente como Classe 4 e, portanto, não seletivos para o predador quando testados em larvas de primeiro instar de *C. genanigra*. Pesquisas em condições de campo e semicampo devem ser realizadas para avaliar a seletividade dos inseticidas testados.

Palavras-chave: Fitossanidade. Melão. Agrotóxicos. Inimigo natural. *Chrysoperla genanigra.*

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***Corresponding author:**
<alcimargaldino80@hotmail.com>

INTRODUCTION

Northeast is one of the most important melon (*Cucumis melo* L.) producing regions in Brazil, where the states of Ceará and Rio Grande do Norte account for more than 70% of the country's melon production (IBGE, 2023).

However, melon plants are attacked by various pests that damage their development and production, causing major economic losses. The leafminer *Liriomyza* sp. (Diptera: Agromyzidae) is the main phytosanitary problem in melon crops, which requires major management investments in the Northeast region of Brazil (FERREIRA et al., 2017).

Despite various technological advances in melon crops, insect pest management is mainly carried out through applications of chemical pesticides, whose intensive use causes environmental contamination and negative impacts on natural enemy populations (CHAGAS et al., 2016). Pesticides can cause lethal and sublethal effects on these beneficial insects, affecting their biology and reducing prey/host populations in agroecosystems (LOETTI; BELLOCQ, 2016). The use of broad-spectrum pesticides can have serious implications for the population dynamics of parasitoids (SILVA et al., 2020; ARAUJO et al., 2015)

and predators (SILVA et al., 2017), and may favor the emergence of pest population outbreaks (HILL; MACFADYEN; NASH, 2017).

The adoption of sustainable practices in the field is necessary to mitigate the harmful effects of pesticides, including the use of selective insecticides, which are known for their efficacy in pest control while causing minimal impact on biological control agents in agricultural crops (BUENO et al., 2017).

Predatory insect species from the family Chrysopidae occur naturally in various agricultural areas, with potential to be used in biological control programs due to their good reproductive capacity, ease of rearing in the laboratory, high predation efficiency, and the availability of selective insecticides (PASINI et al., 2021; SUÁREZ-LÓPEZ et al., 2020).

The residual action of insecticides has been studied for lacewings (Chrysopidae), including *Chrysoperla externa* Hagen, 1861 in peach orchards (CASTILHOS et al., 2017; CASTILHOS et al., 2019), *Chrysoperla carnea* (Stephens, 1836) in maize crops (MAIA et al., 2016) and under laboratory conditions (ABD-ELLA et al., 2022), and *Chrysoperla genanigra* Freitas, 2003 (Neuroptera: Chrysopidae) in melon (SILVA et al., 2017). These studies evaluated different toxicological characteristics of insecticides and established the potential compatibility of their use with biological control in integrated pest management programs.

The use of selective insecticides is a strategy to integrate chemical control with biological control for controlling lacewings. Information about the residual time of these products on these individuals, i.e., the duration that the products maintain a harmful effect on these organisms, allows farmers to use less harmful products and plan application intervals for the most appropriate times (PASINI et al., 2021).

The lacewing *C. genanigra* has been regularly found in melon-growing areas in Rio Grande do Norte, Brazil (BEZERRA et al., 2010); the initial population of individuals used in the present research was captured in this region. However, insecticides are widely applied to these production areas; thus, the direct and indirect impacts of these products on this predator should be studied.

In this context, the objective of this study was to assess the residual toxicity (deleterious effects) of seven insecticides approved for insect pest control in melon plants on the biological aspects of the predator *Chrysoperla genanigra*.

MATERIAL AND METHODS

A bioassay was conducted at the Chemical Product Selectivity Laboratory of the Department of Agronomic and Forestry Sciences of the Federal Rural University of the Semi-Arid Region (UFERSA), in Mossoró, RN, Brazil. Adult lacewings were captured in melon-producing areas in Mossoró using entomological nets and placed in polyvinyl chloride cages. The insects were taken to the laboratory for the identification of species and rearing. The methodology used was based on standards proposed by the International Organization for Biological and Integrated Control of Noxious Animals and Plants (IOBC/WPRS, 1992).

The selected insecticides are commonly recommended for the control of insect pests in melon crops; the highest rates recommended by the manufacturers were used in the trials (Table 1) (AGROFIT, 2023). All insecticides were diluted in distilled water. The experiment was conducted in a completely randomized design, with eight treatments and ten replications, and a control treatment using only distilled water.

Table 1. Insecticides and rates used on melon crops to control first-instar *Chrysoperla genanigra* larvae under laboratory conditions.

Commercial name	Active ingredient	Rates (g a.i. L^{-1})	Chemical group
Azact CE	Azadirachtin	0.024	Tetranortriterpenoid
Batent	Abamectin	0.018	Avermectin
Benevia	Cyantraniliprole	0.1	Anthranilamide
Calypso	Thiacloprid	0.3202	Neonicotinoid
Chess 500 WG	Pymetrozine	0.25	Azomethine Pyridine
Evidence 700 WG	Imidacloprid	0.7	Neonicotinoid
Rimon 100 EC	Novaluron	0.05	Benzoylurea

Insecticide treatments (Table 1) were applied directly onto the glass surface inside Petri dishes (Ø = 10 cm) using 500-mL pressurized manual sprayers with a flow rate of 0.58 mL s^{-1} and an application rate of 1.5±0.5 mL of solution per cm². The plates were left to dry for 30 minutes under ambient conditions.

A first-instar *C. genanigra* larva, up to 24 hours old, was placed individually in each Petri dish to assess the effect of the products on the lacewing's biology. Larvae were fed *Anagasta kuehniella* (Zeller, 1879) (Lepidoptera: Pyralidae) eggs ad libitum, then sealed with cling film and placed in biological development chambers (BOD) at a temperature of 25±2 °C, relative humidity of 70±10%, and 12-hour photoperiod.

Larval mortality was assessed at 1, 3, 6, 9, 12, and 24 hours after exposure to the treatments. Larvae that did not respond to the touch of a fine-tipped brush were considered dead. After this period, survival and instar changes were assessed daily until adult emergence; the adults were then sexed and separated into pairs. Sexing was performed by observing the genitalia, which are dimorphic and located at the end of the insect's abdomen.

Pairs were obtained for each treatment, individualized, and kept in polyvinyl chloride cages (20 cm height and 10 cm diameter), which were internally lined with red suede paper as a substrate for oviposition. Adult insects were fed with a mixture of honey and brewer's yeast (1:1) impregnated on plastic strips and provided with distilled water daily in an

Eppendorf containing moistened absorbent cotton (GODOY et al., 2004). Adult insects were transferred to new cages every two days to remove the suede paper and collect and count the eggs.

Egg viability was analyzed using a 100-egg sample per treatment, placed in enzyme-linked immunosorbent assay (ELISA) microtiter plates covered polyvinyl chloride laminated film and kept until larval hatching, as proposed by Godoy et al. (2004).

Larval and pupal mortality (%), duration of each larval instar and pupal stage (days), sex ratio, number of eggs per female, and egg viability were assessed.

The obtained data were subjected to analysis of variance (One-Way ANOVA) at a 5% significance level. When the assumptions of ANOVA were not met, the data were analyzed using the Kruskal-Wallis test. The formula used to calculate the sex ratio was: (*sex ratio = number of females / number of females + number of males)*. The total mortality data were corrected for each developmental stage using the Abbott's formula (ABBOTT, 1925): $Ma = (Mt - Mc) / (100 - Mc) \times 100$, where *Ma* is the mortality corrected for the control treatment; *Mt* is the total accumulated mortality (%) in the insecticide treatment; and *Mc* is the total accumulated mortality (%) in the control treatment. All data were expressed as means and standard error; the analyses were performed using the SAS 8.0 statistical software.

The toxicity of chemical pesticides was categorized into toxicological classes based on their effects on the mortality of predatory insects, using the total effect formula described by Overmeer (1988): $E = 100\% - (100\% - M_C\%) \times R1 \times R2$, where *E* is the total effect (%); *Mc%* is the mortality corrected for the control treatment (ABBOTT, 1925); *R1* is the ratio between the daily mean numbers of oviposited eggs per treated and untreated females; and *R2* is the ratio between the mean numbers of fertile eggs oviposited per treated and untreated females. The insecticides were classified into four toxicity categories based on mortality: Class 1 = harmless ($E < 30\%$), Class 2 = slightly harmful ($30\% \leq E \leq 79\%$), Class 3 = moderately harmful ($80\% \leq E \leq 99\%$), and Class 4 = harmful ($E \geq 99\%$).

RESULTS AND DISCUSSION

All first-instar larvae of *Chrysoperla genanigra* survived exposure to surfaces treated with the evaluated insecticides during the first 24 hours; however, although not evaluated in the study, their ability to move and feed on *Anagasta kuehniella* eggs tended to reduce.

The effects of the residual toxicity of insecticides, expressed as cumulative mortality, corrected mortality, effects on reproduction, total effect, and toxicity classes are shown in Table 2. First-instar larvae of *C. genanigra* contaminated with novaluron showed 100% mortality, specifically during the molting process to the second instar, after five or six days of exposure to the product. These larvae died with parts of the exuviae retained in the abdomen, denoting the larvicidal action of this product by interfering with ecdysteroid metabolism and inhibiting chitin synthesis (GODOY et al., 2004). Considering the species *C. carnea*, the application of novaluron (topical, residual, or oral) negatively impacted the development of the immature stage, preventing the emergence of adult individuals (AMARASEKARE; SHEARER; MILLS, 2016).

Table 2. Cumulative mortality (%) of *Chrysoperla genanigra* larvae at different developmental stages, total accumulated mortality (M; %), total accumulated mortality corrected by Abbott's formula (1925) (Mc; %), mean number of eggs per day per female (R1), percentage of viable eggs (R2), total effect (E; %), and toxicity class (TC) of insecticides applied to first-instar larvae.

Treatments	Initial population	Cumulative mortality (%)				M	MC	R1	R2	E	TC
		Larval stages			Pupae						
		1st	2nd	3rd							
Control	30	6.67	3.33	0	10	20	-	4.09	3.12	-	-
Azadirachtin	30	56.67	33.33	10.00	-	100	100	-	-	-	4
Abamectin	30	66.67	3.33	23.33	6.67	100	100	-	-	-	4
Cyantraniliprole	30	76.67	3.33	20.00	-	100	100	-	-	-	4
Thiacloprid	30	13.33	13.33	43.33	23.34	93.33	91.66	-	-	100	4
Pymetrozine	30	23.33	3.33	46.67	23.34	96.67	95.84	-	-	100	4
Imidacloprid	30	43.33	13.33	20.00	23.34	100	100	-	-	-	4
Novaluron	30	100	-	-	-	100	100	-	-	-	4

TC = toxicity class of insecticides as a function of total effect (E): Class 4 = harmful (> 99%).

Similar results were found for the insecticide lufenuron, which belongs to the same chemical group as novaluron. According to Castilhos et al. (2019), lufenuron showed a residual and persistent effect for more than 30 days, causing 100% mortality in *C. externa* larvae. Suárez-López et al. (2020) evaluated the topical application and consumption of prey contaminated with lufenuron and found a high mortality rate for larvae at second instar and pupal stages, respectively. Ono et al. (2017) reported that insecticides that inhibit chitin biosynthesis, such as diflubenzuron and lufenuron, are highly harmful to first-instar larvae of *Ceraeochrysa cubana* (Hagen, 1861) (Neuroptera: Chrysopidae), causing 100% mortality before reaching the pupal stage. These results show that benzoylurea-based insecticides are not only growth regulators for phytophagous insects, but can also reduce populations of chrysopids under field conditions, especially when the density of immature individuals is high. Recently, sublethal concentrations of

novaluron have proven to be incompatible with *C. carnea* (ALSENDI et al., 2023).

Azadirachtin, abamectin, and cyantraniliprole had a lethal effect ranging from 57% to 77% on first-instar larvae, while imidacloprid, pymetrozine, and thiacloprid resulted in mortality rates of 13% to 43% (Table 2). According to Pasini et al. (2021), first-instar *C. externa* larvae exposed to a surface contaminated with imidacloprid and beta-cyfluthrin showed 90% mortality, and the residual effect of these products persisted for more than 30 days after treatment.

Second-instar larvae of *C. genanigra* that remained on surfaces contaminated with azadirachtin exhibited approximately 33% mortality. The toxic effect of the other insecticides was relatively low, ranging from 3% mortality (cyantraniliprole, abamectin, and pymetrozine) to 13% (imidacloprid and thiacloprid).

In the last larval instar, treatment with azadirachtin caused the lowest lethality (10%). However, this lethal effect was twice as high as that of treatments with cyantraniliprole, abamectin, and imidacloprid, while those with pymetrozine and thiacloprid were four times more toxic.

Although azadirachtin is one of the most widely used pesticides in for pest control in agricultural crops worldwide, its toxicity and residual effects have been considered low for various biological control agents (KILANI-MORAKCHI; MORAKCHI-GOUDJIL; SIFI, 2021). Nevertheless, several studies have reported deleterious effects of azadirachtin against some species of lacewings, confirming the results obtained for *C. genanigra* in the present study. Delayed development, deformities, and damage to the reproductive system were observed in the predatory species *Ceraeochrysa claveri* (Navás, 1911) (Neuroptera: Chrysopidae) when exposed to azadirachtin (GASTELBONDO-PASTRANA et al., 2019). The sublethal effect of azadirachtin has been reported for *C. cubana*, with reduced viability for pupae from first-instar larvae exposed to this product (RUGNO et al., 2019). In the present study, no first-instar larvae of *C. genanigra* exposed to surfaces treated with azadirachtin or cyantraniliprole completed the third larval instar.

Studies have shown different results regarding the selectivity of some of the insecticides evaluated in the present study for other species of lacewings. Abamectin was considered slightly harmful (Class 2) to first-instar larvae *C. externa* when applied at lower rates (0.0054 or 0.0067 g a.i. L^{-1}) (GODOY et al., 2004). Similar result was found for second- and third-instar larvae of *C. carnea* when this insecticide was applied at higher rates (0.025 g a.i. L^{-1}) (ABD-ELLA et al., 2022) or at the same rate used in the present study (0.0018 g a.i. L^{-1}) (MAIA et al., 2016), respectively.

Chlorantraniliprole belongs to the same chemical group as cyantraniliprole (anthranilamide). It was classified as harmless (Class 1) when first-instar larvae of *C. genanigra* were exposed to the insecticide; however, pymetrozine and imidacloprid were considered harmful when applied to first-instar larvae (SILVA et al., 2017). Godoy et al. (2010) classified imidacloprid as harmless (Class 1) for adults of *C. cubana*, but moderately harmful (Class 3) for *C. externa*.

Despite these differences in the categorization of insecticides, their effects depend not only on the application rate, but also on the method of exposure to the product, the developmental stage of the non-target insects exposed, and the predatory species analyzed.

The shortest first-instar larval stage was found for cyantraniliprole, averaging 2.77 days; azadirachtin and novaluron resulted in the longest time to complete the first larval instar, with means of 5.33 and 5.37 days, respectively. The other insecticides (imidacloprid, thiacloprid, pymetrozine, and abamectin) were significantly similar to the control treatment, with the first-instar larval stage lasting between 3.40 and 4.17 days. Bezerra et al. (2012) studied the biology of *C. genanigra* at 25 °C and found that first-instar larvae lasted 3.2 days, similar result to those found for the treatments with imidacloprid, pymetrozine, and thiacloprid used in the present study, but different from the control treatment (4.03 days).

C. genanigra larvae developed to the second instar stage in all insecticide treatments, except for novaluron, which prevented the larvae from reaching the second instar, probably due to the larvicidal action of products from this chemical group, which inhibits the chitin synthesis and interferes with the insect's ecdysis process (GODOY et al., 2004). The shortest second instar stage was found for the treatment with cyantraniliprole (3.42 days), while larvae in the treatment with abamectin completed the second instar in the longest time (4.61 days). The control and treatments with pymetrozine, thiacloprid, azadirachtin, and imidacloprid showed similar means, with second-instar duration ranging from 3.62 to 4.25 days.

No larvae completed the third larval stage in treatments with decreased or increased duration of the first instar stage (cyantraniliprole and azadirachtin, respectively), with all individuals dying after ten or seven days of exposure to the residues of these insecticides, respectively.

Larvae reached the third instar and showed similar and faster development in the control and abamectin treatments compared to the other treatments, with means of 5.55 and 6.88 days, respectively. Larvae completed the third stage slowly in treatments with pymetrozine, imidacloprid, and thiacloprid, with means from 12.37 to 14.70 days. The durations of the third instar stage varied significantly compared to those obtained by Bezerra et al. (2012) for the same species at 25 ° C; they found shorter durations for all treatments and the control (3.2 to 3.4 days). This difference may be due to the use of a different food source, *Sitotroga cerealella* (Olivier, 1819) eggs, or due to the origin of the predatory population used.

Some lacewings in the control, thiacloprid, and pymetrozine treatments completed the pupal stage, with pupae lasting less (4.64 days) in the treatment with thiacloprid. Larvae in the treatment with pymetrozine did not differ from the control, completing the pupal stage in 7.33 days. Ono et al. (2017) evaluated first-instar larvae of *C. cubana* treated with buprofezin, methoxyfenozide, and tebufenozide and found no difference in pupal stage duration between these treatments and the control (12.8 days). This was much longer time than that observed for *C. genanigra* larvae in the control treatment in the present study (8.43 days).

Regarding adult emergence, females and males had mean longevity of 38.75 and 32.09 days in the control treatment, respectively, with a sex ratio of 0.5. Bezerra et al. (2012) evaluated the biology of *C. genanigra* and reported that the time for half of the insect population to die was approximately 53 days at a temperature of 25 °C, showing greater longevity compared to the control treatment in the present study. Similarly, Ono et al. (2017) reported that the

longevity of female and male *C. cubana* in the control was 73.3 and 86.4 days respectively, showing a longer duration for males compared to females. These results vary depending on the species and within the species, as they are directly affected by edaphoclimatic factors and the quantity and quality of food consumed (SILVA et al., 2017). The number of emerged adults was insignificant in treatments with thiacloprid and pymetrozine, with only one pair or one female for these insecticides, respectively (Table 3).

Table 3. Mean duration (±standard error) of different larval instars and pupal stage, adult longevity, and sex ratio of first-instar larvae of *Chrysoperla genanigra* exposed to insecticide treatments.

Treatments	Duration (days)[1]			
	1st instar	2nd instar	3rd instar	Pupa
Distilled water	4.03±0.14 BC	3.62±0.13 BC	5.55±0.54 B	8.43±0.14 A
Novaluron	5.37±0.24 A	-	-	-
Azadirachtin	5.33±0.43 A	4.11±0.86 AB	-	-
Abamectin	4.17±0.34 AB	4.61±0.51 A	6.88±1.29 B	-
Thiacloprid	3.6±0.16 BC	3.89±0.43 B	14.7±0.85 A	4.64±0.82 B
Pymetrozine	3.6±0.17 BC	3.62±0.23 BC	12.37±1.26 A	7.33±1.31A
Imidacloprid	3.4±0.44 BC	4.25±0.44 AB	13.19±1.28 A	-
Cyantraniliprole	2.77±0.26 C	3.42±0.42 C	-	-

Treatments	Adult longevity (descriptive values)		Sex ratio
	Female	Male	
Distilled water	38.75±10.98	32.09±10.25	0.5
Novaluron	-	-	-
Azadirachtin	-	-	-
Abamectin	-	-	-
Thiacloprid	1.00	1.00	0.5
Pymetrozine	11.00	-	1.0
Imidacloprid	-	-	-
Cyantraniliprole	-	-	-

[1]Means followed by the same letter in the columns are not significantly different from each other by the non-parametric Kruskal-Wallis test at a 0.05 significance level ($p < 0.05$).

First-instar larvae completed the immature phase on surfaces contaminated with residues of abamectin, pymetrozine, imidacloprid, and thiacloprid, but the duration of the larval phase was approximately 18% to 68% longer compared to the control (Table 3). Despite this apparent success or tolerance to residues of these insecticides, adult emergence was zero for abamectin and imidacloprid, one pair for thiacloprid, and only one adult male for pymetrozine. The number of adults in these treatments also differed significantly from the control treatment, where 80% of individuals reached the adult stage, and females laid, on average, 4.09 eggs per day throughout their lives. The reduced number of adults may be attributed to the effects of these products on the feeding and nutrient assimilation processes during the development of the lacewing.

However, treatments with abamectin and thiacloprid did not prevent *C. externa* larvae from developing and reproducing as adults (GODOY et al., 2004); this difference in the impact of these insecticides may be associated with the rates used, which were three to nine times lower. Research conducted on *C. genanigra* showed that the duration of the first-instar larvae exposed to pymetrozine was approximately two days, but none of them reached the second instar (SILVA et al., 2017).

These interferences with the larval development and formation of pupae and adults of *C. genanigra* indicate that the active ingredients of the insecticides remain long enough to reduce the occurrence and beneficial action of this species in melon crops. The non-lethal effects of synthetic insecticides have been reported as one of the factors causing the loss of a natural enemy's ability to establish its populations in various environments, mainly by affecting the physiology, behavior, and neurological processes of these organisms (NDAKIDEMI; MTEI; NDAKIDEMI, 2016).

Twenty of the 121 insecticides approved for melon crops, approximately 17%, have been evaluated for the predator *C. genanigra*, and the only product that proved to be selective (Class 1) for first-instar larvae of this species was Premio® (chlorantraniliprole; 0.0025 g a.i. L^{-1}) (SILVA et al., 2017), a promising insecticide to be integrated into biological pest control programs in melon crops.

The recommended rates by manufacturers for the seven insecticides used may be effective for pest management in melon crops, but they may result in significant deleterious effects on predatory lacewings occurring in agricultural fields. The predatory activity of *C. genanigra*, as well as its abundance and persistence in melon production areas, may be disrupted by the tested insecticides. The toxicity and residual

effects on *C. genanigra* would make these pesticides incompatible for use in integrated pest management programs, specifically in biological control by conservation or mass release of this lacewing species.

CONCLUSION

All tested insecticides (azadirachtin, abamectin, cyantraniliprole, thiacloprid, pymetrozine, imidacloprid, and novaluron) were harmful or non-selective to the predator *Chrysoperla genanigra*, and were classified as Class 4, according to the International Organization for Biological Control, when applied at the highest rates recommended by the manufacturers. However, semi-field and field experiments should be conducted to corroborate the non-selectivity found under laboratory conditions and determine the impacts of sublethal rates of these products on other developmental stages of the lacewing *C. genanigra*.

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