RESEARCH

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Impact of insecticides used to control *Spodoptera frugiperda* (J.E. Smith) in corn on survival, sex ratio, and reproduction of *Trichogramma pretiosum* Riley offspring

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Corn (*Zea mays* L.) is cultivated in large areas and considered one of the world's major cereal crops. There are several arthropod pests that can reduce its production such as the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lep.: Noctuidae), which is considered to be the main pest for corn. Fall armyworm is primarily controlled by insecticides. The use of biological control agents to manage this pest is growing with an emphasis on the egg parasitoid *Trichogramma pretiosum* Riley (Hym.: Trichogrammatidae). Thus, the aim of this research was to evaluate the impact of the following insecticides (g ai L^{-1}) beta-cypermethrin (0.03), chlorfenapyr (0.60), chlorpyrifos (0.96), spinosad (0.16), etofenprox (0.10), triflumuron (0.08), alfa-cypermethrin/teflubenzuron (0.0425/0.0425), and lambda-cyhalothrin/thiamethoxam (0.11/0.083) on survival, sex ratio, reproduction, and *T. pretiosum* offspring. Distilled water was used as a control. Commercial insecticide formulations were diluted in distilled water. Bioassays used *Anagasta kuehniella* eggs treated with insecticides which were afterwards exposed to parasitism. Bioassays were conducted under controlled conditions at 25 ± 2 ºC, 70 ± 10% RH, and 12:12 h photoperiod. Alfa-cypermethrin/teflubenzuron, beta-cypermethrin, chlorpyrifos, chlorfenapyr, spinosad, etofenprox, and lambda-cyhalothrin/thiamethoxam reduced parasitism capacity of maternal generation females as well as the percentage of insect emergence from the F_1 generation. Only triflumuron was selective for *T. pretiosum* and can be recommended along with this parasitoid in fall armyworm management programs in corn.

Key words: Integrated pest management, parasitoid, selectivity, triflumuron, *Zea mays*.

INTRODUCTION

Corn (*Zea mays* L.) is considered to be one of the main cereals produced around the world. It is used for fresh consumption, industry, and animal feeding. Several factors can reduce or compromise both the yield and quality of corn production and insect pests are a major factor. These organisms can cause significant crop damage by reducing production, yield, and causing great economic losses (Carvalho et al., 2010a).

The fall army worm *Spodoptera frugiperda* (J.E. Smith) (Lep.: Noctuidae) is the main pest in corn. Its caterpillar can attack the corn plant in the seedling stage up until the tasseling and silking stages. In Brazil, it is estimated that the fall armyworm is responsible for losses of more than 50% of the damage caused by insect pests that attack corn and most of the spending on pesticide sprayings (Figueiredo et al., 2006). Insecticides are the main method to control *S. frugiperda* in corn in Brazil; however, they damage the environment when they are used indiscriminately. Another control option this pest is the biological control with several beneficial organisms acting as natural enemies, such as parasitoids, predators, fungi, virus, bacteria, and nematodes (Cruz et al., 2002).

Parasitoids belonging to the genus *Trichogramma* are commonly found parasitizing *S. frugiperda* in Brazilian corn crops (Beserra and Parra, 2003); the *Trichogramma pretiosum* Riley (Hym.: Trichogrammatidae) species is associated to numerous hosts and is the most frequent parasitoid occurring in several agroecosystems.

However, for *T. pretiosum* to be a natural regulator of fall armyworm populations, its preservation is necessary. Studies about the side-effects of pesticides on the natural enemies of insect pests must be conducted with the objective of creating information that can help in decision making about integrated pest management (IPM) programs and maintaining these parasitoids in the agroecosystems and contribute in regulating insect pest populations (Moura et al., 2005).

Thus, the aim of this research was to evaluate the impact of some insecticides recommended for controlling fall armyworm in corn on survival, sex ratio, reproduction, and *T. pretiosum* offspring.

MATERIALS AND METHODS

The following insecticides (g ai L^{-1}) were used in the bioassays with *T. pretiosum*: beta-cypermethrin (0.03) [cyano(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-

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2,2-dimethylcyclopropanecarboxylate], chlorfenapyr (0.60) [4-bromo-2-(4-chlorophenyl)-1-(ethoxymethyl)-5-(trifluoromethyl)-1*H*-pyrrole-3-carbonitrile], chlorpyrifos (0.96) [*O*,*O*-diethyl O-(3,5,6-trichloro-2-pyridinyl) phosphorothioate], spinosad (0.16) (mixture of 50% to 95% spinosyn A and 5% to 50% spinosyn D), etofenprox (0.10) [2-(4-ethoxyphenyl)-2-methylpropyl 3-phenoxybenzyl ether], triflumuron (0.08) [1-(2-chlorobenzoyl)-3-(4-trifluoromethoxyphenyl) urea], alpha-cypermethrin/teflubenzuron (0.0425/0.0425) [(*R*)-cyano(3-phenoxyphenyl)methyl (1*S*,3*S*)-rel-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate] + [1-(3,5-dichloro-2,4-difluorophenyl)-3-(2,6-difluorobenzoyl)urea], and lambda-cyhalothrin/thiamethoxam (0.11/0.083) {(*R*)-cyano(3-phenoxyphenyl) methyl (1*S*,3*S*)-rel-3-[(1*Z*)-2-chloro-3,3,3,-trifluoro-1-propenyl]-2,2-dimethylcycloproanecarboxylate} + [(*EZ*)-3-(2-chloro-1,3-thiazol-5-ylmethyl)-5-methyl-1,3,5-oxadiazinan-4-ylidene(nitro)amine]. Rates evaluated in this study correspond to the highest rates recommended for controlling *S. frugiperda* in Brazilian corn crops. Bioassays were conducted under controlled conditions at 25 ± 2 ºC, 70 ± 10% RH, and 12:12 h photoperiod.

Aqueous pesticide solutions were prepared with distilled water. The control consisted of distilled water. Each treatment consisted of 30 *T. pretiosum* females aged 0 to 24 h obtained from rearing, which were then individually placed into glass tubes (8.0 cm height × 2.5 cm diameter) closed at the top with PVC film. Females were fed with a small drop of honey that was applied on the tube inner walls. Blue paper cards (8.0 cm long × 0.5 cm width) containing approximately 125 *Anagasta kuehniella* eggs that were previously UV-killed were glued with diluted Arabic gum. Before being exposed to parasitism, the paper cards containing the host eggs were dipped in the respective aqueous pesticide solution for 5 s. The cards were left to dry at environmental conditions for 1 h.

Treated host eggs were exposed to parasitism at 1, 24, and 48 h after treatment for 24 h. These females were then kept in glass tubes and fed honey at 24-h intervals to evaluate their longevity. Cards containing the parasitized eggs were transferred to new glass tubes, which were kept under the above mentioned controlled conditions. Each treatment had six replicates consisting of five paper cards containing treated host eggs. Side-effects were evaluated for the tested pesticides on both longevity and parasitism capacity of the maternal generation females.

Effects of the tested insecticides on newly emerged females (F_1) from treated host eggs were also evaluated. Thus, 24 females (per treatment) were randomly individualized in glass tubes, fed honey, and the tubes closed with PVC film. Untreated host eggs were offered to these females. Each treatment consisted of six replicates and each plot was made up of four cards containing host eggs. The following biological parameters were evaluated: parasitism capacity, emergence percentage, and sex ratio (F_2).

A completely randomized experimental design in a 3 × 9 (three offer moments × nine treatments) factorial design was used. Data were subjected to ANOVA and the means were compared by a cluster analysis method for grouping means using the Scott-Knott test ($p < 0.05$) (Scott and Knott, 1974) when the *F*-test was significant. On the other hand, survival data (maternal generation) were subjected to contrast analysis to verify differences and similarities among tested insecticides. Data were then subjected to survival analysis by applying the Weibull distribution with a package for Survival Analysis in R™ (R Development Core Team, 2010).

Tested insecticides were then classified based on the reduction of the beneficial capacity caused to the parasitoid in accordance with the International Organization for Biological Control (IOBC) (Sterk et al., 1999): class 1 = harmless (< 30% reduction either in parasitism capacity or emergence), class 2 = slightly harmful (30% to 79% reduction), class 3 = moderately harmful (80% to 99% reduction), and class 4 = harmful (> 99% reduction). The percentage reduction of the beneficial capacity (parasitism and emergence) was obtained by Equation [1]:

$$\text{Reduction} = 100 - \left[\left(\frac{\text{Insecticide}}{\text{Control}}\right) x100\right] \qquad [1]$$

RESULTS AND DISCUSSION

Alpha-cypermethrin/teflubenzuron, beta-cypermethrin, etofenprox, lambda-cyhalothrin/thiamethoxam, and triflumuron had values which were also similar to the control treatment regarding the longevity of *T. pretiosum* females exposed to treated *A. kuehniella* eggs at 1, 24, and 48 h after treatment. Mean lethal time (LT_{50}) values obtained for these compounds were 11.5, 10.27, and 10.27 d, respectively (Figures 1A-C).

Results obtained for etofenprox in this study were similar to those observed for the evaluated pyrethroid-based insecticides (either alone or combined with other compounds). It is believed that the highest longevity values observed for females exposed to pyrethroid-treated host eggs are related to their repellent effect on this parasitoid species. This effect was also verified by Carvalho et al. (2001), who found that *T. pretiosum* females avoided contact with pyrethroid-treated host eggs. Etofenprox is likely to have caused the same repellent effect since it exhibits a similar chemical structure to that of pyrethroid-based insecticides (Yoshimoto et al., 1989; Weerasinghe et al., 2001; Gunning et al., 2007). However, the physiological bases that could explain this phenomenon are not yet clear. Our findings for triflumuron corroborate the results obtained by Carvalho et al. (2010b), who evaluated the effect of this insecticide (0.14 g ai L^{-1}) on

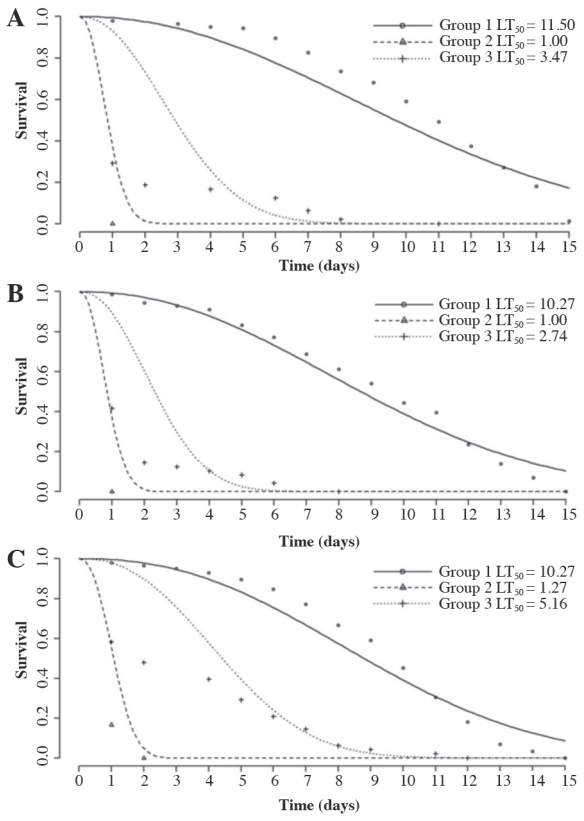

Figure 1. Longevity of *Trichogramma pretiosum* females exposed to treated *Anagasta kuehniella* eggs, 1 h (A), 24 h (B), and 48 h (C) after treatment where: $y = \exp(\mu^{-\alpha})*(x^{\alpha})$ and y = survival; $\mu = LT_{50}$ (lethal time 50); $\alpha_{1\ h} = 2.114165$, $\alpha_{24\ h} = 2.164502$, and $\alpha_{48\ h} = 2.358491$; x = Time (d); Group 1 = control, alpha-cypermethrin/teflubenzuron, beta-cypermethrin, etofenprox, lambda-cyhalothrin/thiamethoxam, and triflumuron; Group 2 = chlorpyrifos; Group 3 = chlorfenapyr and spinosad.

T. pretiosum female longevity immediately, 24, and 48 h after spraying; they found that this compound did not affect this biological parameter. Goulart et al. (2012) also verified that triflumuron (0.096 g ai L^{-1}) is harmless to both *T. pretiosum* and *Trichogramma exiguum* Pinto and Platner, 1978.

Insect growth regulator (IGR) insecticides belong to the benzoylureas chemical class and these compounds are usually harmless for adult parasitoids of the genus *Trichogramma*. Its selectivity is probably related to the IGR mode of action since these insecticides act on the new cuticle formation of the insect as a chitin synthesis inhibitor, which does not occur in adult insects (Carvalho et al., 2003; 2010b; Maia et al., 2010).

Chlorfenapyr and spinosad also negatively affected female longevity and provided intermediary LT_{50} values when compared with other tested compounds. The LT_{50} values obtained for these insecticides were approximately 3.5, 2.7, and 5.1 d for females exposed to treated host eggs at 1, 24, and 48 h after treatment, respectively (Figures 1A-C).

Regardless of exposure time, it was verified that spinosad reduced the longevity of females that maintained contact with treated host eggs. This effect can be due to its action mode since the coupling of the spinosad molecule to the nicotinic acetylcholine receptors (nAChR) leads to the opening of ion channels (Cl^-) in the postsynaptic membrane and causes both hyperexcitability of the central nervous system (CNS) and death of the treated insects. According to Salgado (1998) and Salgado et al. (1998), the spinosad molecule can also act on the receptors of the neurotransmitter gamma-aminobutyric acid (GABA), which are present in the CNS of insects and affect their functioning. Similar results were observed by Maia et al. (2010), who found that spinosad (0.16 g ai L^{-1}) reduced longevity of *Trichogramma atopovirilia* Oatman & Platner, 1983 exposed to treated *A. kuehniella* eggs at 24, 48, and 96 h after treatment. Studies developed by Hussain et al. (2010) (0.20 g ai L^{-1}) and by Sattar et al. (2011) (0.12 g ai L^{-1}) with *Trichogramma chilonis* Ishii (1941) also showed reduced longevity of this beneficial caused by spinosad, which demonstrates its high toxicity in parasitoids of the genus *Trichogramma*.

Findings reported in this study for chlorfenapyr are similar to those obtained by Moura et al. (2004) for the same parasitoid species. These authors also found reduced longevity of females that stayed in contact with chlorfenapyr-treated (0.12 g ai L^{-1}) host eggs at 1, 24, and 48 h after treatment with means of 2.8, 3.1, and 1.3 d, respectively.

Values of LT_{50} for chlorfenapyr seem to be associated with its mode of action. Chlorfenapyr is a pro-insecticide member of the "pyrrole" chemical family, which must be converted into an active form before it can cause this effect by enzyme action called mixed function oxidases. The toxic form of chlorfenapyr, identified as CL 303268, uncouples oxidative phosphorylation in the mitochondria, which disrupts ATP (adenosine triphosphate) production and energy loss leading to cell dysfunction and subsequent insect death (Black et al., 1994; Sato et al., 2007; Raghavendra et al., 2011).

Chlorpyrifos, on the other hand, proved to be very harmful for *T. pretiosum* females, regardless of the moment when the parasitoid was exposed to chlorpyrifos-treated host eggs. The LT_{50} values obtained for chlorpyrifos were 1.0, 1.0, and 1.27 d, respectively (Figures 1A-C). Our results verify that chlorpyrifos is very harmful to the parasitoid under study. Several studies have demonstrated the high toxicity of insecticides belonging to the organophosphate chemical group for different *Trichogramma* species.

Moscardini et al. (2008) and Nörnberg et al. (2011) verified that the fenitrothion and methidathion, and chlorpyrifos and malathion insecticides, respectively, were harmful to *T. pretiosum* and reduced its parasitism capacity due to the high mortality rates recorded. Studies conducted by Maia et al. (2010) with *T. atopovirilia* and by Hussain et al. (2010) with *T. chilonis* also indicated

high toxicity of chlorpyrifos for both *Trichogramma* species. The impact of organophosphate insecticides on parasitoids of the genus *Trichogramma* was also observed by other authors (Hassan et al., 1994; Carvalho et al., 1999; Sterk et al., 1999; Moura et al., 2006).

High toxicity exhibited by insecticides belonging to the organophosphate chemical group is associated with their action mechanism that occurs by inhibiting the nerve impulse transmission across synapses. In both nervous tissues and neuromuscular junctions, organophosphate insecticides bind to the enzyme acetylcholinesterase (AChE) exactly in the active site responsible for neurotransmitter acetylcholine (ACh) degradation, which accumulates since this neurotransmitter is not degraded by AChE. The coupling of an organophosphate insecticide and the enzyme AChE by the serine hydroxyl group inactivates the enzyme and forms a complex called organophosphate-AChE. The organophosphate-AChE complex is slowly hydrolyzed and leads to the accumulation of the neurotransmitter in both neuron-neuron and neuron-muscle junctions; this severely alters the synaptic transmission of nerve impulses, which can culminate in the hyperexcitation of the nervous system and result in insect death (Omoto, 2000; Rigitano and Carvalho, 2001).

Regarding the impact of the tested insecticides on *T. pretiosum* parasitism capacity, only triflumuron did not reduce the number of parasitized eggs when offered 24 and 48 h after treatment with means of 18.4 and 21.1 eggs per female, respectively. However, triflumuron decreased this parasitoid's parasitism capacity 1 h after treatment. The other compounds reduced parasitism capacity with means varying from 0.04 to 8.33 eggs per female (Table 1).

Chlorpyrifos reduced parasitism capacity of *T. pretiosum* females by 99.8% and 99.3% at 1 and 24 h after treatment, respectively and was classified as harmful (class 4) for this parasitoid species. When chlorpyrifos-treated host eggs were offered to these females 48 h after treatment, a decrease of 96.9% was observed in parasitism capacity and the compound was considered moderately harmful (class 3) (Table 1).

Moura et al. (2006) and Stefanello Júnior et al. (2008a; 2008b) also observed that chlorpyrifos drastically reduced *T. pretiosum* parasitism capacity and classified the pesticide as harmful (class 4).

Alpha-cypermethrin/teflubenzuron,beta-cypermethrin, lambda-cyhalothrin/thiamethoxam and etofenprox were classified as moderately harmful (class 3), whereas chlorfenapyr was considered slightly harmful (class 2). Spinosad reduced in 90.7% the parasitism capacity, 1 h after treatment, and was considered moderately harmful (class 3); however, parasitism capacity of tested females decreased in 79.5% and 78.6% at 24 and 48 h after treatment, respectively, and was classified as slightly harmful (class 2) (Table 1). It is believed that the observed reductions in parasitism capacity of *T. pretiosum* exposed to pyrethroid-based insecticides can also be associated with their repellent effect as reported by Carvalho et al. (2001) and/or to inhibition of parasitism behavior caused by these compounds for this parasitoid species.

Our findings for etofenprox are similar to those reported by Moscardini et al. (2008), who observed that this insecticide negatively affected *T. pretiosum* parasitism capacity with a mean reduction of 98.5%, which ranks the compound as moderately harmful (class 3). Results reported in this study for chlorfenapyr are also similar to those obtained by Moura et al. (2004), who observed a reduction of 46% in *T. pretiosum* parasitism capacity. These authors also classified chlorfenapyr as slightly harmful (class 2). Stefanello Júnior et al. (2008a) showed that triflumuron did not affect *T. pretiosum* parasitism capacity when tested females were exposed to triflumuron-treated host eggs; this was similar to the findings of the present

Table 1. Mean number (± SE) of eggs parasitized by *Trichogramma pretiosum* females (maternal and F_1 generations) when maternal females were exposed to *Anagasta kuehniella* treated eggs.

Treatment	1 h after treatment			24 h after treatment			48 h after treatment		
	Number of eggs	PR[1]	Class[2]	Number of eggs	PR[1]	Class[2]	Number of eggs	PR[1]	Class[2]
	Maternal generation[3]								
Control	25.20 ± 2.08aA	-	-	19.33 ± 3.76aB	-	-	21.62 ± 3.33aB	-	-
Beta-cypermethrin	0.33 ± 0.37dA	98.69	3	1.16 ± 1.24dA	93.96	3	1.08 ± 0.62cA	94.99	3
Chlorfenapyr	7.45 ± 4.36cA	70.41	2	8.33 ± 2.35bA	56.89	2	5.37 ± 3.37bA	75.14	2
Chlorpyrifos	0.04 ± 0.10dA	99.83	4	0.12 ± 0.30dA	99.35	4	0.66 ± 0.64cA	96.91	3
Spinosad	2.33 ± 0.87dA	90.74	3	3.95 ± 1.13cA	79.52	2	4.62 ± 2.83bA	78.61	2
Etofenprox	5.04 ± 3.07cA	80.00	3	1.58 ± 0.87dB	91.81	3	1.33 ± 0.87cB	93.83	3
Triflumuron	21.79 ± 3.62bA	13.53	1	18.45 ± 4.75aB	4.52	1	21.12 ± 4.41aA	2.31	1
Alpha-cypermethrin/teflubenzuron	1.00 ± 0.63dA	96.03	3	0.83 ± 0.25dA	95.68	3	0.54 ± 0.33cA	97.49	3
Lambda-cyhalothrin/thiamethoxam	0.37 ± 0.37dA	98.51	3	0.54 ± 0.57dA	97.19	3	0.45 ± 0.40cA	97.88	3
	F_1 generation								
Control	26.79 ± 8.31aA	-	-	30.72 ± 6.12aA	-	-	22.61 ± 2.72aA	-	-
Triflumuron	27.75 ± 9.08aA	0.00	1	29.77 ± 6.36aA	3.09	1	24.49 ± 9.32aA	0.00	1

[1]Percentage reduction of parasitism capacity.
[2]Toxicity class proposed by Sterk et al. (1999) in which class 1 = harmless, class 2 = slightly harmful, class 3 = moderately harmful, and class 4 = harmful.
[3]Figures followed by the same letter, lower case in columns and upper case in rows, show no differences between them according to Scott-Knott test ($P > 0.05$) (Scott and Knott, 1974); $CV_{\text{maternal generation}}$ (%) = 35.9 and $CV_{F1\ \text{generation}}$ (%) = 27.2.

research study. It was possible to evaluate side-effects on F_1 parasitoids only for triflumuron when parasitism rates varied from 24.4 to 29.7 eggs per female; this insecticide was classified as harmless (Table 1).

Beta-cypermethrin decreased emergence success of F_1 parasitoids by 100% when treated host eggs were offered to maternal females 1 h after treatment and was considered harmful (class 4). On the other hand, when beta-cypermethrin-treated host eggs where offered to *T. pretiosum* females 24 and 48 h after treatment, emergence decreased by 68.5% and 65.9%, respectively and the insecticide was classified as slightly harmful (class 2). Chlorfenapyr allowed low *T. pretiosum* emergence (23.4%, 27.1%, and 21%) and was classified as slightly harmful (class 2) (Table 2).

Alpha-cypermethrin/teflubenzuron and lambda-cyhalothrin/thiamethoxam reduced emergence success by approximately 87% and 82% (1 h after treatment) and approximately 86% and 95% (48 h after treatment), respectively, for F_1 parasitoids; both insecticides were classified as moderately harmful (class 3). For treated host eggs offered to parasitism 24 h after treatment, these insecticides reduced emergence by approximately 43% and 70%, respectively, and were considered slightly harmful (class 2) (Table 2).

Spinosad was classified as moderately harmful (class 3) since it decreased emergence success of F_1 parasitoids regardless of the time when the treated eggs were exposed to maternal females with means varying from 81.5% to 98.5% (Table 2). Sex ratio of F_1 and F_2 parasitoids was not negatively affected by triflumuron, which had means ranging from 0.57 to 0.71. The other tested insecticides reduced this biological trait of *T. pretiosum* (Table 3). Only triflumuron allowed us to assess the sublethal effects caused by the tested insecticides to F_2 parasitoids, which is considered harmless to *T. pretiosum* (Tables 1, 2, and 3).

Table 3. Sex ratio (± SE) of *Trichogramma pretiosum* (F_1 and F_2) from *Anagasta kuehniella* treated eggs and exposed to parasitism[1].

Treatment	1 h after treatment	24 h after treatment	48 h after treatment
		F_1 generation	
Control	0.67 ± 0.10aA	0.63 ± 0.11aA	0.53 ± 0.14aA
Beta-cypermethrin	-	0.13 ± 0.11cA	0.21 ± 0.04bA
Chlorfenapyr	0.32 ± 0.23bA	0.31 ± 0.16bA	0.29 ± 0.20bA
Chlorpyrifos	-	-	0.14 ± 0.12b
Spinosad	0.08 ± 0.12cB	0.20 ± 0.18bA	0.00 ± 0.00cB
Etofenprox	0.25 ± 0.15bA	0.26 ± 0.22bA	0.19 ± 0.19bA
Triflumuron	0.61 ± 0.12aA	0.57 ± 0.11aA	0.62 ± 0.16aA
Alpha-cypermethrin/ teflubenzuron	0.07 ± 0.10cB	0.23 ± 0.15bA	0.05 ± 0.10cB
Lambda-cyhalothrin/ thiamethoxam	0.12 ± 0.20cA	0.14 ± 0.15cA	0.04 ± 0.10cA
		F_2 generation	
Control	0.60 ± 0.15aA	0.74 ± 0.05aA	0.64 ± 0.12aA
Triflumuron	0.63 ± 0.08aA	0.71 ± 0.03aA	0.57 ± 0.19aA

[1]Figures followed by the same letter, lower-case in columns and uppercase in rows, show no differences between them according to Scott-Knott test ($P > 0.05$) (Scott and Knott, 1974); $CV_{F1\ generation}$ (%) = 5.66 and $CV_{F2\ generation}$ (%) = 3.78; (-) Traits not evaluated due to high mortality rate caused by insecticides.

CONCLUSIONS

In conclusion, chlorfenapyr, chlorpyrifos, and spinosad reduced longevity of *T. pretiosum* females exposed to treated host eggs. Both parasitism capacity (maternal generation) and emergence success (F_1) were reduced by all tested insecticides with the exception of triflumuron, which was considered selective to *T. pretiosum*. Only triflumuron did not affect sex ratio of this parasitoid species.

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Table 2. Percentage of emergence (± SE) of *Trichogramma pretiosum* (F_1 and F_2 generations) from *Anagasta kuehniella* treated eggs and exposed to parasitization at different moments by maternal and F_1 females.

Treatment	1 h after treatment			24 h after treatment			48 h after treatment		
	Emergence (%)	PR[1]	Class[2]	Emergence (%)	PR[1]	Class[2]	Emergence (%)	PR[1]	Class[2]
				F_1 generation[3]					
Control	67.24 ± 6.86aA	-	-	67.80 ± 6.67aA	-	-	71.44 ± 10.18aA	-	-
Beta-cypermethrin	0.00 ± 0.00dB	100.00	4	21.29 ± 15.48cA	68.59	2	24.30 ± 10.00bA	65.97	2
Chlorfenapyr	23.48 ± 15.44cA	65.07	2	27.15 ± 9.24cA	59.95	2	21.09 ± 15.38bA	70.47	2
Chlorpyrifos	0.00 ± 0.00dB	100.00	4	0.00 ± 0.00dB	100.00	4	15.50 ± 10.88bA	78.22	2
Spinosad	2.78 ± 5.04dB	95.86	3	12.51 ± 12.41dA	81.54	3	1.04 ± 2.55cB	98.54	3
Etofenprox	45.61 ± 13.17bA	32.16	2	33.47 ± 19.94cA	50.63	2	13.88 ± 12.97bB	80.55	3
Triflumuron	59.72 ± 9.77aA	20.78	1	58.44 ± 6.89aA	13.80	1	66.93 ± 10.99aA	6.30	1
Alpha-cypermethrin/teflubenzuron	8.75 ± 6.84dB	86.98	3	38.19 ± 21.47bA	43.66	2	9.72 ± 15.29cB	86.39	3
Lambda-cyhalothrin/thiamethoxam	11.80 ± 14.53dA	82.44	3	20.13 ± 16.33bA	70.29	2	3.47 ± 5.53cB	95.13	3
				F_2 generation					
Control	74.29 ± 21.23aA	-	-	87.11 ± 6.86aA	-	-	85.68 ± 12.58aA	-	-
Triflumuron	87.55 ± 11.35aA	0.00	1	82.78 ± 8.46aA	4.97	1	82.69 ± 15.65aA	3.48	1

[1]Percentage reduction of emergence success.
[2]Toxicity class proposed by Sterk et al. (1999) in which: class 1 = harmless, class 2 = slightly harmful, class 3 = moderately harmful, and class 4 = harmful.
[3]Figures followed by the same letter, lower-case in columns and uppercase in rows, show no differences between them according to Scott-Knott test ($P > 0.05$) (Scott and Knott, 1974); $CV_{F1\ generation}$ (%) = 39.0 and $CV_{F2\ generation}$ (%) = 16.3.

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