

Selectivity of Insecticides Against *Telenomus podisi* Ashmead (Hymenoptera: Platygasteridae) on Corn

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Received: July 20, 2018

Accepted: September 17, 2018

Online Published: November 15, 2018

doi:10.5539/jas.v10n12p185

URL: <https://doi.org/10.5539/jas.v10n12p185>

Abstract

Use of synthetic insecticides remains main control strategy for percevejo-marrom (*Euschistus heros*) in corn. However, indiscriminate use of these products can have adverse effects on the environment and human health. Thus, incorporation of bio-agents like *Telenomus podisi* a preferred option in corn pest management. Study was conducted to evaluate the effects of insecticides application on *T. podisi* mortality rates, the number of eggs parasitized by the F₀ generation, and number of emergent F₁ parasitoids. The insecticides tested were: imidacloprid+bifenthrin, bifenthrin+carbosulfan, thiametoxam+lambda-cyhalothrin, acephate, bifenthrin, and imidacloprid at the highest concentrations indicated for corn. Each insecticide was classified according to its selectivity, based on the methodology proposed by IOBC/WPRS. Only imidacloprid did not affect parasitoid survival however the parasitism rates of F₀ females, were affected, classifying this product as slightly harmful for this biological trait. Regarding parasitoid emergence (F₁), thiametoxam+lambda-cyhalothrin was classified as moderately harmful, while bifenthrin+carbosulfan and bifenthrin were considered harmful, no parasitism occurred. Thus the evaluated insecticides were classified as slightly harmful to the parasitoid *T. podisi* under laboratory conditions for the biological characteristics evaluated. Further studies under semi-field and field conditions are needed in order to confirm these toxicity levels on *T. podisi*.

Keywords: integrated pest management, biological control, parasitoids

1. Introduction

Corn *Zea mays* L., is a grain of great economic importance in Brazil. It is wider in use at processing industry where it is processed into a wide range of products including livestock feed as well as in the high technology industry Ministério da Agricultura, Pecuária e Abastecimento (MAPA, 2012). However, this crop is attacked by insect pests that can cause extensive crop losses to farmers (Grigolli & Lourenção, 2013).

Among these insect pests, the Neotropical brown stinkbug, *Euschistus heros* (Fabricius, 1798), has become economically important (Quintela, Ferreira, Guimarães, L. F. C. de Oliveira, A. C. Oliveira, & Czepak, 2006), due to its adverse economic impacts that include stunted growth, unproductive plants, and lower yields (Jandrey, 2014; Viana, 2016).

Recently the economic impact of sucking insect pests in corn has become more pronounced, as reflected in a 65% increase in corn fields requiring/reporting treatment in 2015 season. The average cost of field applications rose from R\$ 22 to 26 per hectare, because farmers made more applications to control sucking insects and used more products to spray treatments: 11% of the treatments combined two insecticide products and 96% of the treated areas received two specific applications for stinkbugs (Kleffmann Group, 2016).

Chemical control is the most used method against sucking insects in corn because it is practical and effective, but it has adverse effects on humans, animals, and the environment (Mendes, Boregas, Lopes, Waquil, & Waquil, 2011). Thus other methods have been used, such as biological control with egg parasitoids, *Telenomus* sp. These parasitoids have the advantage of controlling the pest before damage to the crop occurs (Parra, Botelho, Côrrea, & Bento, 2002), and *Telenomus podisi* Ashmead was considered the main factor affecting the mortality of *E. heros* under field conditions (Godoy, Galli, & Ávila, 2005). However, the use of non-selective chemicals

adversely affect natural enemies and reduce the effectiveness of biological control. Several studies have shown adverse effects of chemicals on *Telenomus remus* (Carmo, A. F. Bueno, R. C. O. F. Bueno, Vieira, Gobbi, & Vasco, 2009; Vieira, Boff, A. F. Bueno, Gobbi, Lobo, & R. C. O. F. Bueno, 2012), *Trissolcus* sp., (González, Laumann, Silveira, Moraes, Borges, & Ferreira, 2013), *Trichogramma galloi* (Oliveira, Antigo, Carvalho, Glaeser & Pereira, 2013), *Telenomus podisi* (Smaniotto, Gouvea, Potrich, E. R. L. Silva, J. Silva & Pegorini, 2013; Turchen, Golin, Butnariu, Guedes, & Pereira, 2015; Pazini, Pasini, Seidel, Rakes, Martins, & Grutzmacher, 2017), among other egg parasitoids.

The goal of an Integrated Pest Management (IPM) program is to combine control methods that complement and do not adversely affect each other. Therefore, it is important to test the selectivity of several pesticides that can be used with some natural enemies in IPM programs. Studies have shown that chlorantraniliprole and *M. anisopliae* are not harmful (class 1) to *T. galloi* adults, since they do not affect the survival, parasitism, or emergence of this parasitoid, making it possible to use them in combination with insecticides (Oliveira et al, 2013).

Similarly, the abundance of *Chrysodeixis includens* Walker (Lepidoptera: Noctuidae) is lower in soybean treated with *Baculovirus anticarsia* (AgMNPV), because this microbial control agent does not adversely affect biological control agents (Corrêa-Ferreira, Alexandre, Pellizzaro, Moscardi, & Bueno, 2010). In contrast, chemical insecticides, due to their harmful effects on natural enemies, have been shown to increase the number of *C. includens* larvae (Bueno, Carvalho, Santos, Sosa-Gómez, & Silva, 2017). Therefore, parasitoids, entomopathogens, and chemicals can be used simultaneously, but compatibility needs to be evaluated (Polanczyk, Pratisoli, Dalvi, Grecco & Franco, 2010; Oliveira et al, 2013).

Most studies regarding toxicity on egg parasitoids are focused on lepidopteran insects (Carmo, A. F. Bueno, & R. C. O. F. Bueno, 2010; Oliveira et al., 2013; Golin, 2014), while few toxicological studies target pentatomids. Thus studies including other orders of insects are needed. This study was aimed at evaluating the selectivity of chemical products used in corn to control *E. heros* for the egg parasitoid *T. podisi*.

2. Material and Methods

Bioassays to evaluate of the selectivity of products for the parasitoid *Telenomus podisi* were carried out at the Laboratory of Entomology of the Federal University of Grande Dourados, Dourados-MS, Brasil. All tests were performed and maintained in a climate chamber at 25±2 °C, 60±10% RH, and 12-hour (L:D) photophase. The products tested were commercial formulations of the insecticides imidacloprid+bifenthrin (400 mL/ha), bifenthrin+carbosulfan (500 mL/ha), thiamethoxam+lambda-cyhalothrin (250 mL/ha), acephate (800 g/ha), bifenthrin (300 mL/ha), imidacloprid (250 mL/ha), as they are the most commonly used to control *E. heros* in corn in Brazil. Distilled water was used as a control.

2.1 Bioassay I: Assessment of Adult Mortality

A day old twenty *T. podisi* females were individually maintained in glass tubes (10 × 90 mm) and fed with droplet of pure honey placed on the inner wall of the tube, that was sealed with PVC film perforated with an entomological pin for aeration. Subsequently, rectangles of blue card stock paper (1.0 × 3.0 cm), each containing 50 eggs of *E. heros* attached with 10% gum arabic, were immersed for five seconds in a solution of one of the chemical products tested (Good et al, 2008). Card stock rectangles were then removed from the bath and allowed to dry on paper towel at room temperature for one hour to remove the excess liquid. The eggs were then exposed for 24 hours to individual females in the tubes, in order to evaluate the selectivity of the insecticides for adult parasitoids.

2.2 Bioassay II: Assessment of Parasitism

To assess egg parasitism rates, eggs were treated with the test insecticides, twenty card stock rectangles with eggs were individually placed in a glass tube with one *T. podisi* female, as proposed by Brugger et al. (2010) and Vianna et al. (2009). Parasitism rates (number of eggs parasitized by females for 24 hours) were calculated.

2.3 Bioassay III: Adult Emergence in Insecticide-Treated Eggs

In order to examine possible effects of insecticide-treated eggs on the larval development and emergence rate of the parasitoid was calculated (number of eggs with exit holes of the parasitoid/total number of parasitized eggs) × 100] based on twenty replicates, following the methodology described in the previous bioassay.

2.4 Statistical Analysis and Classification of Insecticides

The experimental design was randomized with seven treatments (six insecticides and one control group). Each treatment consisted of 20 replicates (each replicate composed of a card stock paper with 50 *E. heros* eggs). The groups were compared with an analysis of variance and the Tukey test with a level of significance of 1%.

According to recommendations of the International Organization for Biological and Integrated Control (IOBC), the tested insecticides were also classified into toxicological classes based to the percentage of reduction (PR) of the parasitoid's beneficial capacities (mortality, parasitism, and emergency) compared to the control group, calculated as : $PR = [100 - (\% \text{ overall mean of insecticide treatment} / \text{general mean of control group})] \times 100$.

In accord with IOBC recommendations, the tested insecticides were classified by the percentage reduction (PR) of parasitoid beneficial abilities (survival, parasitism, and emergence) in relation to the control treatment: class 1 = innocuous, reduction less than 30%; class 2 = slightly harmful, 30-79%; class 3 = moderately harmful, 80-99%; and class 4 = harmful, > 99% (Serk et al., 1999).

3. Results

3.1 Bioassay I

The mortality rates of *T. podisi* (F_0) females that were in contact with *E. heros* eggs treated with the insecticides thiametoxam+lambda-cyhalothrin, bifenthrin, imidacloprid+bifenthrin, bifenthrin+carbosulfan, and acephate were statistically higher when compared to imidacloprid and the control group. According to the reduction in mortality, the treatment with thiametoxam+lambda-cyhalothrin was classified as moderately harmful (Class 3), while bifenthrin, imidacloprid+bifenthrin, bifenthrin+carbosulfan and acephate were slightly harmful (Class 2). Imidacloprid was classified as innocuous (Class 1), thus not reducing the survival of *T. podisi* (Table 1).

Table 1. Mortality (%) (\pm SD), percentage of reduction (PR) and toxicological class of *Telenomus podisi* in eggs of *Euschistus heros* treated with corn insecticides in a selectivity test. Means followed by the same lowercase letter in the column do not differ by Tukey ($p > 0.05$)

Treatments	Commercial Product Dose (P.C)	Mortality (%)	PR ¹ (%)	Class ²
Control	-	0.00 \pm 0.00 c	-	-
Imidacloprid+Bifentrina	400 mL/ha	65.0 \pm 0.10 a	65.0	2
Bifentrina+Carbosulfano	500 mL/ha	60.0 \pm 0.11 a	60.0	2
Thiamethoxam+Lambda-Cialotrina	250 mL/ha	80.00 \pm 0.11 a	80.00	3
Acefato	800 g/ha	55.0 \pm 0.09 ab	55.0	2
Bifentrina	300 L/ha	75.00 \pm 0.09 a	75.0	2
Imidacloprid	250 mL/ha	15.0 \pm 0.08 c	15.0	1

Note. ¹Average percentage of parasitism reduction in *T. podisi*. ²Toxicity classes recommended by Serk et al. (1999).

3.2 Bioassay II

Regarding the number of parasitized eggs of *T. podisi* on *E. heros* eggs treated with insecticides, among the six products tested, only acephate (reduction of parasitism rate of 67.08%) and imidacloprid (reduction of parasitism rate of 32.01%) were classified as slightly harmful (Class 2). The insecticides thiametoxam+lambda-cyhalothrin (reduced parasitism by 97.55%) and imidacloprid+bifenthrin (reduced parasitism by 95.56%) were classified as moderately harmful, while bifenthrin and bifenthrin+carbosulfan (reduced parasitism in more than 99%) were classified as harmful (Table 2).

Table 2. Number (\pm EP) of parasitized eggs and percentage of reduction (PR) of *Telenomus podisi* in eggs of *Euschistus heros* treated with corn insecticides in a selectivity test. Means followed by the same lowercase letter in the column do not differ by Tukey ($p > 0.05$)

Treatments	Commercial Product Dose (P.C)	Mean number of eggs parasitized by <i>T. podisi</i> (n = 50*)	% eggs parasitized of <i>T. podisi</i>	PR ¹ (%)	Class ²
Control	-	32.65 \pm 1.49 a	65.30	-	-
Imidacloprid+Bifentrina	400 mL/ha	1.45 \pm 0.35 d	4.00	95.56	3
Bifentrina+Carbosulfano	500 mL/ha	0.15 \pm 0.08 d	2.00	99.55	4
Thiamethoxam+Lambda-Cialotrina	250 mL/ha	0.80 \pm 0.17 d	2.00	97.55	3
Acefato	800 g/ha	10.75 \pm 0.75c	21.50	67.08	2
Bifentrina	300 L/ha	0.10 \pm 0.06 d	2.00	99.70	4
Imidacloprid	250 mL/ha	22.20 \pm 2.53 b	44.40	32.01	2

Note. *Mean number the parasitized eggs based on total number of eggs per replicate (50 eggs repetition). ¹Mean percentage of parasitismo reduction in *T. podisi*. ²Toxicity classes recommended by Sterk et al. (1999).

3.3 Bioassay III

The emergence rates of *T. podisi* (F₁) from *E. heros* eggs treated with imidacloprid+bifenthrin, acephate, and imidacloprid were not affected, when compared to the control group and the insecticides were classified as innocuous (Class 1) for this trait. Only bifenthrin+carbosulfan and bifenthrin had adverse effects (Class 4), as they reduced parasitoid emergence by more than 99% (Table 3).

Table 3. Emergence (\pm EP) and percentage of reduction (PR) of *Telenomus podisi* in eggs of *Euschistus heros* treated with corn insecticides in a selectivity test. Means followed by the same lowercase letter in the column do not differ by Tukey ($p > 0.05$)

Treatments	Commercial Product Dose (P.C)	% of emergency <i>T. podisi</i>	PR ¹ (%)	Class ²
Control	-	87.05 \pm 0.02a	-	-
Imidacloprid+Bifentrina	400 mL/ha	65.30 \pm 0.11 a	24.99	1
Bifentrina+Carbosulfano	500 mL/ha	0.00 \pm 0.00 b	-	4
Thiamethoxam+Lambda-Cialotrina	250 mL/ha	10.25 \pm 0.07 b	88.25	3
Acefato	800 g/ha	82.40 \pm 0.03 a	5.35	1
Bifentrina	300 L/ha	0.00 \pm 0.00 b	-	4
Imidacloprid	250 mL/ha	80.05 \pm 0.04 a	8.05	1

Note. ¹Mean percentage reduction in the emergence of *T. podisi*. ²Toxicity classes recommended by Sterk et al. (1999).

4. Discussion

Contact with eggs treated with thiamethoxam+lambda-cyhalothrin resulted in a mortality rate of 80% in *T. podisi* females. This insecticide belongs to the neonicotinoid+pyrethroid chemical group and these active ingredients are not very selective (Cañete, 2005; Lim & Mahmoud, 2008; Koppel, Herbert, Kuhar, Malone, & Arrington, 2011). Treatment with this same chemical resulted in mortality rates up to 100% in *T. podisi* Turchen et al. (2015).

Rapid death and high mortality rates are generally expected when using neurotoxic insecticides, based on their mode of action. For example, pyrethroids are sodium channel blockers acting on axonal neurotransmission, whereas neonicotinoids are agonists of different subtypes of nicotinic acetylcholine receptors in the synapses of the insect central nervous system (Casida & Durkin, 2013; Turchen et al., 2015). This also explains the results obtained for insecticides of the same chemical group imidacloprid+bifenthrin, bifenthrin and bifenthrin+carbosulfan, which were classified as slightly harmful to the survival of *T. podisi*.

The acephate-based insecticide was also detrimental to the survival of *T. podisi*, as it belongs to the organophosphorus chemical group, and affects insects mainly by phosphorylating the enzyme acetylcholinesterase (AChE). This results in loss of available AChE and organ overstimulation due to excess

acetylcholine in nerve endings, affecting natural enemies and pests in a similar way. This insecticide is available on the market at more accessible prices to farmers who often overuse it (Carmo et al., 2010). However according to our findings, this product is not compatible with biological control practices.

Bifenthrin+carbosulfan and bifenthrin-based insecticides of the pyrethroid and benzofuranyl methylcarbamate groups reduced parasitism and emergence rates of *T. podisi*, as also reported for the parasitoids *T. remus* (Carmo et al., 2010) and *T. pretiosum* (Pinto, Magano, Pasini, Spagnol, Anjos, & Grutzmacher, 2012).

The insecticides acephate (organophosphate) and imidacloprid (neonicotinoid) act by contact and ingestion, disorganizing the nervous system of insects (Carmo et al., 2009). The effects of these insecticides on parasitism rates in the present study were classified as slightly harmful (Class 2), which may be associated to its mode of action, thus preventing a high rate of parasitism by parasitoids. On the other hand, when parasitoid emergence was evaluated, no harmful effects were observed (Class 1). Similar results were obtained for *T. pretiosum* (Carvalho, Fuini, Rocha, Reis, Moraes, & Ecole, 2003; A. F. Bueno, R. C. O. F. Bueno, Parra, & Vieira, 2008), *T. remus* (Carmo et al., 2010), and *T. podisi* (Turchen et al., 2015). However, this same product, used in the same dosage of this study, can vary from harmless to harmful, depending on the developmental stage of the natural enemy (Souza, Carvalho, Moura, Couto & Maia, 2014). Parasitoid pupae and larvae might be more resistant to pesticides, compared to adults, because they develop inside the host egg, which is protected against insecticides by the chorion (Stecca, Bueno, Pasini, Silva, Andrade, & Filho, 2016).

The results obtained for the pesticides imidacloprid+bifenthrin and thiametoxam+lambda-cyhalothrin were considered moderately harmful. Other recent studies also reported similar results (Turchen et al., 2015).

In contrast, only bifenthrin+carbosulfan and bifenthrin adversely affected the emergence of parasitoids (Table 3). Similar results were found for bifenthrin on the emergence of *T. remus* (Carmo et al., 2010). These results are expected, since these insecticides are more likely to affect parasitism rates than emergence, as they do not appear to interfere in the development of larvae and pupae of the parasitoid inside the host egg, due to the protection provided by the chorion (Carmo et al., 2009; Turchen, Golin, Butnariu, & Pereira, 2014; Turchen et al., 2015).

Regardless of the evaluated biological characteristics of the parasitoid, our findings indicated that the insecticides with more than one active ingredient had the most harmful effects on *T. podisi* parasitoids. Among the insecticides used with these characteristics are: thiametoxam+lambda-cyhalothrin (neonicotinoid+pyrethroid), bifenthrin+imidacloprid (pyrethroid+neonicotinoid), and bifenthrin+carbosulfan (pyrethroid+benzofuranil methylcarbamate).

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