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Selectivity of pesticides used in rice crop on *Telenomus podisi* and *Trichogramma pretiosum*[1]

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ABSTRACT

Telenomus and *Trichogramma* species stand out as agents for the biological control in rice crops, and the main strategy for preserving them is the use of selective pesticides. This study aimed at evaluating the toxicity of pesticides used in irrigated rice crop on *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae) and *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae). Adults of these parasitoids were exposed to dry residues of pesticides, in a completely randomized experiment, with 25 treatments (24 pesticides + control) and four replications. The insecticides clorantraniliprole, flubendiamide and diflubenzuron and the biological insecticides based on *Beauveria bassiana* and *Metarhizium anisopliae* were harmless to *T. podisi* and *T. pretiosum*. The harmless herbicides were: 2.4-D amine, profoxydim, quinclorac, ethoxysulfuron and saflufenacil. The fungicide epoxiconazole + kresoxim-methyl was also harmless to these two biological control agents. Therefore, these pesticides are indicated for the integrated pest management, in flooded rice areas.

KEY-WORDS: *Oryza sativa*; egg parasitoids; integrated pest management.

RESUMO

Seletividade de pesticidas utilizados em arroz sobre *Telenomus podisi* e *Trichogramma pretiosum*

Espécies de *Telenomus* e *Trichogramma* destacam-se como agentes de controle biológico em áreas orizícolas, e a principal estratégia para sua preservação é a utilização de agrotóxicos seletivos. Objetivou-se avaliar a toxicidade de agrotóxicos utilizados em áreas de arroz irrigado sobre *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae) e *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae). Adultos desses parasitoides foram expostos a resíduos secos de agrotóxicos, em experimento inteiramente casualizado, com 25 tratamentos (24 agrotóxicos + testemunha) e quatro repetições. Os inseticidas clorantraniliprole, flubendiamida e diflubenzurom e os inseticidas biológicos à base de *Beauveria bassiana* e *Metarhizium anisopliae* foram inócuos para *T. podisi* e *T. pretiosum*. Os herbicidas inócuos foram: 2,4-D amina, profoxidim, quincloraque, etoxissulfurom e saflufenacil. O fungicida epoxiconazol + cresoxim-metílico também foi inócuo para esses dois agentes de controle biológico. Portanto, esses agrotóxicos são indicados para o manejo integrado de pragas, em áreas de arroz irrigado.

PALAVRAS-CHAVE: *Oryza sativa*; parasitoide de ovos; manejo integrado de pragas.

INTRODUCTION

Rice is one of the cereals with greatest economic and social importance worldwide, and Brazil is the largest producer outside the Asian continent (FAO 2015). Despite the high yield, in Brazil, rice crops are subject to the action of numerous pest organisms that cause economic losses. The predominant method for pest control consists of applying pesticides (Pazini et al. 2015), which can exert a negative influence on the population of natural enemies of insect pests (Lou et al. 2013).

The *Telenomus* and *Trichogramma* genera stand out as egg parasitoids of stinkbugs and lepidopterans that are being used for biological control in rice crops (Ko et al. 2014). *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae) is a generalist species that parasitizes a wide range of hosts. *T. podisi* is among the most abundant species associated with oviposition of heteropterans in a number of crops (Pacheco & Corrêa-Ferreira 2000, Maruyama et al. 2002, Godoy et al. 2005), such as in eggs of *Tibraca limbativentris* Stal (Hemiptera: Pentatomidae) (Riffel et al. 2010, Idalgo et al. 2013)

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and *Glyphepomis adroguensis* Berg (Hemiptera: Pentatomidae) (Farias et al. 2012) found in irrigated rice.

Egg parasitoids of the *Trichogramma* genus are reported as agents for the biological control of Lepidoptera pests in irrigated rice crops (Rani et al. 2007), in many countries. Some of the hosts are the eggs of the Asiatic rice borer *Chilo suppressalis* (Walker) (Lepidoptera: Crambidae) (Chen et al. 2010, Ko et al. 2014), the rice leafroller *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae) (Gurr et al. 2012) and the rice yellow stem borer *Scirpophaga incertulas* (Walker) (Lepidoptera: Crambidae) (Guo et al. 2002), among others. In Brazil, several species of *Trichogramma* have been described (Querino & Zucchi 2003), and *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) is one of the most used for controlling Lepidoptera pests (Brugger et al. 2010, Stefanello Júnior et al. 2012).

The use of pesticides in rice crops is a reality, and integrated pest management is an alternative required (Sosbai 2014). Therefore, one strategy for the preservation of the parasitoids is to use selective insecticides, herbicides and fungicides, as well as other chemical and biological agents more harmless to natural enemies (Biondi et al. 2012). However, there is a lack of information on the adverse effects of the main insecticides, herbicides and fungicides on eggs parasitoids used for biological control in Brazil, in rice crops.

This study aimed at evaluating the selectivity of pesticides (insecticides, herbicides and fungicides) used in irrigated rice crop on adults of *T. podisi* and *T. pretiosum* egg parasitoids.

MATERIAL AND METHODS

The study was conducted at the Universidade Federal de Pelotas, in Capão do Leão, Rio Grande do Sul State, Brazil, between 2014 and 2015. The procedures followed standards adapted from the International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) (Hassan et al. 2000, Carmo et al. 2010).

Eggs of alternate hosts *Anagasta kuehniella* (Zeller) (Lepidoptera: Pyralidae) (Parra 1997) and *Euschistos heros* (Fabricius) (Hemiptera: Pentatomidae) (Borges et al. 2006) and adults of *T. pretiosum* (Hassan et al. 2000) and *T. podisi* (Perez & Corrêa-Ferreira 2004, Silva et al. 2008) were obtained from mass rearing in the laboratory (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %; photophase: 14 h).

A total of 24 pesticides that are commonly used in irrigated rice crop were evaluated on adults of *T. podisi* and *T. pretiosum* (Table 1). Selectivity bioassays were conducted with insecticides, herbicides and fungicides and a control treatment (distilled water). The doses used followed the registered maximum doses for rice and/or irrigated rice (Agrofit 2015) (Table 1), adjusted to a mix volume of 200 L ha^{-1}. The experimental design adopted was completely randomized, with 25 treatments (24 products + control) and four replications.

For the selectivity bioassays on adults of *T. podisi*, eggs of *E. heros* parasitized by *T. podisi* (± 50 eggs) were deposited in emergence tubes (glass bottles of 12 cm long x 2 cm in diameter in one end and 0.7 cm in another) with a few drops of pure honey. The tubes were placed in an acclimatized room (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %; photophase: 14 h), until the parasitoids emergence. The pesticides were sprayed on glass plates (13 cm x 13 cm), in a Potter tower, calibrated to deposit 1.75 ± 0.25 mg of mix per cm^2. The edges of the plates were protected by a square plastic structure, so that only the central area measuring 10 cm x 10 cm was sprayed. After the drying period, the plates were fixed in contact cages, in a circulating air system (Hassan et al. 2000). The outer surfaces of the plates that were not treated were covered with black paper, with a square-shaped cut in the center (7 cm x 7 cm), in order to concentrate the parasitoids in the treated area, attracted by the light. Emergence tubes with adult parasitoids (24 h of age) were attached to the cages, which were kept in an acclimatized room (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %; photophase: 14 h).

Twenty hours later, the emergence tubes were uncoupled. Eggs of *E. heros* (cards with ± 100 eggs) were offered to the parasitoids in the cages, at 24 h, 48 h and 72 h after the pesticides spraying. The experiment was terminated after 96 h of parasitoids exposure to pesticide residues. After this period, the cards of eggs were removed from the cages and stored under the same test conditions to check for parasitism.

For the selectivity bioassays on adults of *T. pretiosum*, eggs of *A. kuehniella* parasitized by *T. pretiosum* (250 ± 50 eggs) were placed in emergence tubes containing a few drops of pure honey and stored (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %, photophase: 14 h) until the emergence of the parasitoids. The methods used for pesticide sprays, insertion of insects into the cages and coupling/decoupling of emergence tubes were the same previously described for the toxicity test with *T. podisi*.

Eggs of *A. kuehniella* on cards containing 450 ± 50 eggs each were offered to the parasitoids in cages at 24 h (three cards), 48 h (two cards) and 96 h (one card) after the pesticides spraying. The experiment was terminated after 168 h of parasitoids exposure to pesticide residues. After this period, the cards of eggs were removed from the cages and stored under the same test conditions to check for parasitism.

The mean number of parasitized eggs per female in each treatment was used to estimate parasitism. The parasitism reduction, compared to the control treatment, was calculated by the equation PR (%) = [(1 - Vt/Vc) * 100], where *PR* is the percentage of parasitism reduction, *Vt* the mean parasitism for the treatment and *Vc* the mean parasitism in the control treatment. Thereby, the pesticides were classified according to the IOBC standards: class 1: harmless (PR < 30 %); class 2: slightly harmful (30 % ≤ PR ≤ 79 %); class 3: moderately harmful (80 % ≤ PR ≤ 99 %); class 4: harmful (PR > 99 %).

The data on the mean number of eggs per female parasitized were subjected to the Shapiro-Wilk normality test and homogeneity of variances by the Bartlett test. If these assumptions were not met, the Kruskal-Wallis non-parametric analysis was carried out, and the average of the treatments were compared by the Dunn test, at 5 %. In case of normality and equality of variances, the means were compared by the Scott-Knott test, at 5 %. The R software 3.2.0 (R Development Core Team 2015) was used to carry out the tests.

Table 1. Pesticides used in irrigated rice crop on *Telenomus podisi* and *Trichogramma pretiosum*.

Commercial product (c.p.)®	Active ingredient	Formulation and concentration[I]	Dose of c.p./ha[II]
	Insecticide		
Altacor	Chlorantraniliprole	WG 350	0.09
Belt*	Flubendiamide	SC 480	0.07
Boveril	*Beauveria bassiana*	WP -	0.50
Engeo Pleno	Lambda-cyhalothrin + thiamethoxam	SC 106 + 141	0.20
Incrível	Acetamiprid + alpha-cypermethrin	SC 100 + 200	0.25
Karate Zeon 50 CS	Lambda-cyhalothrin	SC 50	0.15
Klap	Fipronil	SC 200	0.06
Metarril	*Metarhizium anisopliae*	WP -	0.50
Micromite 240 SC	Diflubenzuron	SC 240	0.10
Mustang 350 EC	Zeta-cypermethrin	EC 350	0.04
Safety	Etofenprox	EC 300	0.30
	Herbicide		
Aminol 806	2.4-D amine	SL 806	1.50
Aura 200	Profoxydim	DC 200	0.85
Facet	Quinclorac	WP 500	0.75
Gladium	Ethoxysulfuron	WG 600	0.13
Heat	Saflufenacil	WG 700	0.14
	Fungicide		
Aproach Prima	Picoxystrobin + cyproconazole	SC 200 + 80	0.40
Brio	Epoxiconazole + kresoxim-methyl	SC 125 + 125	1.00
Dithiobin 780 WP	Thiophanate-methyl + mancozeb	WP 140 + 640	2.50
Eminent 125 EW	Tetraconazole	EW 125	0.50
Folicur 200 EC	Tebuconazole	EC 200	0.75
Fox*	Trifloxystrobin + prothioconazole	SC 150 + 175	0.40
Nativo 300 SC	Trifloxystrobin + tebuconazole	SC 100 + 200	0.75
Priori Xtra	Azoxystrobin + cyproconazole	SC 200 + 80	0.30

* Pesticides unregistered for rice and/or irrigated rice crop - registration dose in soybean crop (Agrofit 2015). [I] Formulation and concentration (mL L^{-1} or g kg^{-1}) - EC: emulsifiable concentrate; EW: emulsion, oil in water; DC: dispersible concentrate; SC: suspension concentrate; SL: soluble concentrate; WG: water dispersible granule; WP: wettable powder. [II] Maximum dose of commercial product (c.p.) registered for rice and/or irrigated rice crop (L or kg of c.p. ha^{-1}) (Agrofit 2015).

RESULTS AND DISCUSSION

Significant differences were observed in the parasitism reduction of *T. podisi* and *T. pretiosum* between the treatments with insecticides (Table 2). Chlorantraniliprole, flubendiamide, diflubenzuron and the biological insecticides based on *Beauveria bassiana* and *Metarhizium anisopliae* did not differ from the control, in terms of number of eggs parasitized, and were classified as harmless (class 1), with a parasitism reduction of no more than 10 % for both parasitoids (Table 2).

The harmlessness of chlorantraniliprole was reported for *T. pretiosum* and other species of parasitoid eggs (Hymenoptera: Trichogrammatidae), such as *Trichogramma dendrolimi* Matsumura, *Trichogramma chilonis* Ishii and *Trichogramma japonicum* Ashmead (Preetha et al. 2009, Brugger et al. 2010, Uma et al. 2014). Similarly, flubendiamide is harmless to non-target organisms, such as predators and parasitoids (Sudhanan et al. 2014). Insecticides of the Diamides chemical group, such as chlorantraniliprole and flubendiamide, act on ryanodine receptors (Ebbinghaus-Kintscher et al. 2007), which cause insect death by preventing the normal muscle contractions of the insect. These compounds are very selective, since they act more specifically on phytophagous insects, primarily the Lepidoptera order (Stecca et al. 2014). In addition, they are considered harmless to natural enemies (Lahm et al. 2009), because they act by contact primarily through ingestion, as evidenced by our contact test with dry pesticide residues (Table 2).

Diflubenzuron was also selective to *Telenomus remus* Nixon (Hymenoptera: Platygastridae) (Carmo et al. 2010) and *T. pretiosum* (Carvalho et al. 1994). Insecticides like diflubenzuron, which is an insect growth regulator, have the ability to kill specifically the target insect and preserve the agents of biological control. Hormones that trigger the physiological molting process have different efficacy among the taxonomic orders of insects (Carmo et al. 2010). Pests and their natural enemies are generally from different orders. Moreover, insect growth regulators affect immature stages of insects during the whole molting process (Reynolds 1987), and, thus, adults of non-target species, such as parasitoids and predators, are rarely affected (Bastos et al. 2006). Lufenuron, triflumuron and novaluron, belonging to the Benzoylurea chemical group, as well as diflubenzuron, were also described as harmless to *T. pretiosum* (Carvalho et al. 2010) and may

Table 2. Effect of insecticides and biological insecticides used in irrigated rice crop on the mean number of parasitized eggs, parasitism reduction of *Telenomus podisi* and *Trichogramma pretiosum* and selectivity classification (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %; photophase: 14 h).

Active ingredient	*Telenomus podisi*			*Trichogramma pretiosum*		
	Eggs/female ($\bar{x}$ ± EP)[I]	Parasitism reduction (%)[II]	Class[III]	Eggs/female ($\bar{x}$ ± EP)	Parasitism reduction (%)	Class
Bioassay 1						
Chlorantraniliprole	5.7 ± 0.6 a[#]	1.7	1	24.4 ± 4.5 a*	0.1	1
Lambda-cyhalothrin + Thiamethoxam	0.0 ± 0.0 c	100.0	4	0.0 ± 0.0 b	100.0	4
Lambda-cyhalothrin	0.1 ± 0.1 bc	97.9	3	0.0 ± 0.0 b	100.0	4
Fipronil	0.0 ± 0.0 c	100.0	4	0.0 ± 0.0 b	100.0	4
Etofenprox	1.8 ± 0.1 b	68.8	2	0.0 ± 0.0 b	100.0	4
Control	5.8 ± 0.3 a	-	-	24.4 ± 0.8 a	-	-
Bioassay 2						
Flubendiamide	5.4 ± 0.6 a[##]	0.0	1	17.5 ± 1.6 a**	9.7	1
Beauveria bassiana	6.0 ± 0.3 a	0.0	1	19.0 ± 4.0 a	1.5	1
Acetamiprid + alpha-cypermethrin	1.7 ± 0.1 b	65.0	2	0.7 ± 0.3 b	96.6	3
Metarhizium anisopliae	4.3 ± 0.3 a	9.0	1	23.0 ± 5.2 a	0.0	1
Diflubenzuron	4.7 ± 0.9 a	1.6	1	17.5 ± 1.5 a	9.3	1
Zeta-cypermethrin	0.0 ± 0.0 c	100.0	4	0.0 ± 0.0 b	100.0	4
Control	4.8 ± 0.7 a	-	-	19.3 ± 2.0 a	-	-

[I] Mean + standard error (four replications) of parasitized eggs per female after 96 h (*T. podisi*) and 168 h (*T. pretiosum*) of parasitoids exposure to pesticide residues. [#] Results by Kruskal-Wallis (H = 21.2010; p-value = 0.0007), followed by the Dunn test (p < 0.05). * Results by Kruskal-Wallis (H = 21.8216; p-value = 0.0006), followed by the Dunn test (p < 0.05). [##] Results by Anova (F = 17.4249; p-value = < 0.0001), followed by the Scott-Knott test (p < 0.05). ** Results by Kruskal-Wallis (H = 17.5981; p-value = 0.0073), followed by the Dunn test (p < 0.05). [II] Parasitism reduction in comparison to the control treatment. [III] IOBC classes: 1 = harmless (< 30 %); 2 = slightly harmful (30-79 %); 3 = moderately harmful (80-99 %); 4 = harmful (> 99 %). Means followed by the same letter, in the columns, do not differ significantly.

be recommended for integrated pest management programs.

In line with the results obtained in this study, *M. anisopliae* was previously observed to be selective to adults of *T. podisi*, and did not affect their parasitism and viability, even when the parasitoids were exposed to direct contact with the fungus (Agüero & Neves 2014). Amaro et al. (2015) assessed the toxicity of entomopathogens on adults of *T. pretiosum* and found that biological insecticides with the basis of *B. bassiana* and *M. anisopliae* do not reduce parasitism and are classified as harmless, meaning that they can be used safely in combination with the parasitoid. In addition, there was no reduction in the number of eggs parasitized by *T. pretiosum*, even in sprays of entomopathogens in pre and post-parasitism (Potrich et al. 2009).

Etofenprox and acetamiprid + alpha-cypermethrin, however, were classified as slightly harmful (class 2) to *T. podisi*, with number of eggs parasitized per female of 1.8 and 1.7, representing a parasitism reduction, in relation to the control, of approximately 70 % (Table 2). On the other hand, the remaining insecticides were more harmful to *T. pretiosum*. Acetamiprid + alpha-cypermethrin was classified as moderately harmful (class 3) and etofenprox as harmful (class 4), with high reductions in parasitism of up to 100 % (Table 2). Lambda-cyhalothrin reduced parasitism of *T. podisi* and *T. pretiosum* by 97-100 %, while lambda-cyhalothrin + thiamethoxam, fipronil and zeta-cypermethrin reduced by 100 %, being classified as harmful (class 4) to both parasitoids (Table 2).

Neurotoxic insecticides, such as those belonging to the Pyrethroids and Neonicotinoids chemical groups, are generally classified as less-selective compounds to the egg parasitoids *Telenomus* spp. and *Trichogramma* spp. (Moura et al. 2006, Giolo et al. 2007, Stefanello Júnior et al. 2008a, Preetha et al. 2009, Carmo et al. 2010, Koppel et al. 2011, Goulart et al. 2012, Oliveira et al. 2013). As reported by Stefanello Júnior et al. (2008a), this toxicity originates from the similarity in the transmission mode of nerve impulses not only between the different orders of insects, but also between the various animal phyla.

There was no significant difference for the number of eggs parasitized by females of *T. podisi* and *T. pretiosum* between the herbicide treatments, therefore, all products were classified as harmless (class 1) (Table 3).

The results indicated that the herbicides had little effect on *T. podisi* and *T. pretiosum* populations. This is highly relevant, given that weeds are the main limiting factor for rice yield, and weed control is generally performed using herbicides (Sosbai 2014). Low toxicity to egg parasitoids in different developmental stages was also reported for herbicides registered for soybean (Carmo et al. 2009, Magano et al. 2013) and maize (Stefanello Júnior et al. 2008b and 2011).

Fungicides toxicity showed no significant difference for the average number of eggs parasitized by females of *T. podisi* and were classified as harmless to the parasitoid (Table 4). Fungicide sprays in rice fields predominate in the late booting stage of plants (Counce et al. 2000, Sosbai 2014), and the use

Table 3. Effect of herbicides used in irrigated rice crops on the mean number of parasitized eggs, parasitism reduction of *Telenomus podisi* and *Trichogramma pretiosum* and selectivity classification (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %; photophase: 14 h).

Active ingredient	*Telenomus podisi*			*Trichogramma pretiosum*		
	Eggs/female ($\bar{x}$ ± EP)[I]	Parasitism reduction (%)[II]	Class[III]	Eggs/female ($\bar{x}$ ± EP)	Parasitism reduction (%)	Class
2.4-D amine	5.1 ± 0.4*[ns]	6.6	1	22.7 ± 1.2**[ns]	7.0	1
Profoxydim	5.2 ± 1.3	5.2	1	19.6 ± 3.6	19.6	1
Quinclorac	4.7 ± 0.2	14.1	1	22.4 ± 2.6	8.3	1
Ethoxyssulfuron	4.3 ± 0.4	21.0	1	23.5 ± 5.7	3.6	1
Saflufenacil	4.4 ± 0.9	19.9	1	19.0 ± 2.8	22.0	1
Control	5.7 ± 0.3	-	-	24.4 ± 0.92	-	-

[I] Mean + standard error (four replications) of parasitized eggs per female after 96 h (*T. podisi*) and 168 h (*T. pretiosum*) of parasitoids exposure to pesticide residues. * Results by Anova: F = 0.3967; p-value = 0.8446; [ns] non-significant (p > 0.05). ** Results by Anova: F = 0.4420; p-value = 0.8118; [ns] non-significant (p > 0.05). [II] Parasitism reduction in comparison to the control treatment. [III] IOBC classes: 1 = harmless (< 30 %); 2 = slightly harmful (30-79 %); 3 = moderately harmful (80-99 %); 4 = harmful (> 99 %).

Table 4. Effect of fungicides used in irrigated rice crop on the mean number of parasitized eggs, parasitism reduction of *Telenomus podisi* and *Trichogramma pretiosum* and selectivity classification (temperature: 25 ± 1 ºC; relative humidity: 70 ± 10 %; photophase: 14 h).

Active ingredient	*Telenomus podisi*			*Trichogramma pretiosum*		
	Eggs/female ($\bar{x}$ ± EP)[I]	Parasitism reduction (%)[II]	Class[III]	Eggs/female ($\bar{x}$ ± EP)[I]	Parasitism reduction (%)	Class
		Bioassay 1				
Epoxiconazole + kresoxim-methyl	4.0 ± 0.4[ns#]	9.4	1	20.0 ± 2.1 b*	24.6	1
Thiophanate-methyl + mancozeb	3.7 ± 0.2	15.3	1	7.4 ± 0.9 d	72.3	2
Tetraconazole	5.1 ± 0.7	0.0	1	5.4 ± 0.9 d	79.7	2
Trifloxystrobin + tebuconazole	4.9 ± 0.3	0.0	1	14.1 ± 1.8 c	47.0	2
Control	4.4 ± 0.3	-	-	26.6 ± 2.0 a	-	-
		Bioassay 2				
Picoxystrobin + cyproconazole	4.7 ± 0.5[ns##]	13.4	1	0.5 ± 0.3 d**	98.2	3
Tebuconazole	4.5 ± 0.7	18.0	1	5.4 ± 0.7 bc	77.7	2
Trifloxystrobin + prothioconazole	4.5 ± 0.3	17.0	1	1.0 ± 0.3 cd	96.0	3
Azoxistrobina + ciproconazol	4.7 ± 0.8	15.0	1	17.0 ± 2.8 ab	30.0	2
Control	5.47 ± 0.39	-	-	24.3 ± 1.1 a	-	-

[I] Mean + standard error (four replications) of parasitized eggs per female after 96 h (*T. podisi*) and 168 h (*T. pretiosum*) of parasitoids exposure to pesticide residues. [#] Results by Anova: F = 2.1349; p-value = 0.1267; [ns] non-significant (p > 0.05). * Results by Anova (F = 29.5532; p-value = < 0.0001), followed by the Scott-Knott test (p < 0.05). [##] Results by Anova: F = 0.4993; p-value = 0.7367; [ns] non-significant (p > 0.05). ** Results by Kruskal-Wallis (H = 17.2000; p-value = 0.0018), followed by the Dunn test (p < 0.05). [II] Parasitism reduction in comparison to the control treatment. [III] IOBC classes: 1 = harmless (< 30 %); 2 = slightly harmful (30-79 %); 3 = moderately harmful (80-99 %); 4 = harmful (> 99 %). Means followed by the same letter, in the columns, do not differ significantly.

of selective compounds does not affect the potential for natural parasitism of stinkbug eggs occurring after this period in the crop (Riffel et al. 2010, Idalgo et al. 2013). Other studies also describe the reduced effect of the fungicides Triazole and Strobilurins on adults, larvae and pupae of *T. remus*, in soybean crops (Carmo et al. 2009 and 2010).

Fungicides were more harmful to *T. pretiosum*, if compared to *T. podisi*. Thiophanate-methyl + mancozeb, tetraconazole, trifloxystrobin + tebuconazole, tebuconazole and azoxystrobin + cyproconazole were classified as slightly harmful (class 2) (Table 4). Picoxystrobin + cyproconazole and trifloxystrobin + prothioconazole, however, were classified as moderately harmful (class 3). Only epoxiconazole + kresoxim-methyl was harmless (class 1) for both parasitoids. Magano et al. (2015) obtained similar results with these compounds in a study on the side effects of fungicides registered for disease control on adults of *T. pretiosum*, in soybean.

In general, adults of *T. podisi* seem to be more tolerant than adults of *T. pretiosum* to the toxic effects of insecticides, herbicides and fungicides (Tables 2, 3 and 4). Carmo et al. (2009) also observed this difference, with *T. remus* being more tolerant than *T. pretiosum*, both in the egg and pupa phases.

It is important to consider that, based on the methodology used in this study, the adults from the egg parasitoids were subjected to the maximum contact with pesticides, under laboratory conditions and no-choice tests. Under field conditions, pesticide effects may be minimized by their own degradation, or even because parasitoids may escape to untreated areas. Thus, additional tests under semi-field and/or field conditions, with the pesticides classified as moderately harmful (class 3) and harmful (class 4), recommended by the IOBC (Hassan et al. 2000), should be carried out for the completion of the side effects classification.

Information obtained in this study constitutes a pioneering and important step to choose pesticides selective to egg parasitoids used for the integrated pest management of lowland rice crops. In addition, this information may be useful to integrate management practices for the preservation of these natural enemies in other crops also conducted in this agro-ecosystem, such as soybean and maize.

CONCLUSIONS

1. The chemical insecticides chlorantraniliprole, flubendiamide, diflubenzuron; biological insecticides based on *Beauveria bassiana* and *Metarhizium anisopliae*; herbicides 2.4-D amine, profoxydim, quinclorac, ethoxysulfuron and saflufenacil; and fungicide epoxiconazole +

kresoxim-methyl are harmless to *Telenomus podisi* and *Trichogramma pretiosum*, and are therefore the most suitable for the integrated pest management in flooded rice areas;

2. The insecticides lambda-cyhalothrin + thiamethoxam, lambda-cyhalothrin, fipronil, etofenprox, acetamiprid + alpha-cypermethrin and zeta-cypermethrin, as well as the fungicides picoxystrobin + cyproconazole and trifloxystrobin + prothioconazole, are harmful to at least one of the agents for biological control and are, therefore, not recommended for the integrated pest management in flooded rice areas;
3. *T. podisi* has higher tolerance than *T. pretiosum* to pesticides used in flooded rice areas.

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REFERENCES

AGROFIT: sistema de agrotóxicos fitossanitários. 2015. Available at: <http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons>. Access on: Dec. 14, 2015.

AGÜERO, M. A. F.; NEVES, P. M. O. J. Seletividade de *Metarhizium anisopliae* a *Telenomus podisi* (Hymenoptera: Platygastridae). *Investigación Agraria*, v. 16, n. 1, p. 21-28, 2014.

AMARO, J. T. et al. Selectivity of organic products to *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae). *Neotropical Entomology*, v. 44, n. 5, p. 489-497, 2015.

BASTOS, C. S.; ALMEIDA, R. P. de; SUINAGA, F. A. Selectivity of pesticides used on cotton (*Gossypium hirsutum*) to *Trichogramma pretiosum* reared on two laboratory-reared hosts. *Pest Management Science*, v. 62, n. 1, p. 91-98, 2006.

BIONDI, A. et al. Using organic-certified rather than synthetic pesticides may not be safer for biological control agents: selectivity and side effects of 14 pesticides on the predator *Orius laevigatus*. *Chemosphere*, v. 87, n. 7, p. 803-812, 2012.

BORGES, M. et al. *Metodologias de criação e manejo de colônias de percevejos da soja (Hemiptera - Pentatomidae) para estudos de comportamento e ecologia química*. Brasília, DF: Embrapa Recursos Genéticos e Biotecnologia, 2006.

BRUGGER, K. E. et al. Selectivity of chlorantraniliprole to parasitoid wasps. *Pest Management Science*, v. 66, n. 10, p. 1075-1081, 2010.

CARMO, E. L. do et al. Pesticide selectivity for the insect egg parasitoid *Telenomus remus*. *BioControl*, v. 55, n. 4, p. 455-464, 2010.

CARMO, E. L. do et al. Seletividade de diferentes agrotóxicos usados na cultura da soja ao parasitoide de ovos *Telenomus remus*. *Ciência Rural*, v. 39, n. 8, p. 2293-2300, 2009.

CARVALHO, G. A. et al. Selectivity of growth regulators and neonicotinoids for adults of *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). *Revista Colombiana de Entomologia*, v. 36, n. 2, p. 195-201, 2010.

CARVALHO, G. A. et al. Seletividade de inseticidas reguladores de crescimento de insetos a *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae). *Anais da Sociedade Entomológica do Brasil*, v. 23, n. 3, p. 431-434, 1994.

CHEN, H. F. et al. Control efficacy of *Trichogramma japonicum* against *Chilo suppressalis* and *Chilaraea auricilia*. *Chinese Journal of Applied Ecology*, v. 21, n. 3, p. 743-748, 2010.

COUNCE, P. A. et al. A uniform, objective, and adaptative system for expressing rice development. *Crop Science*, v. 40, n. 2, p. 436-443, 2000.

EBBINGHAUS-KINTSCHER, U. et al. Flubendiamide, the first insecticide with a novel mode of action on insect ryanodine receptors. *Pflanzenschutz-Nachr Bayer*, v. 60, n. 2, p. 117-140, 2007.

FARIAS, P. M. de et al. First records of *Glyphepomis adroguensis* (Hemiptera, Pentatomidae) and its parasitoid, *Telenomus podisi* (Hymenoptera, Platygastridae), on irrigated rice fields in Rio Grande do Sul, Brazil. *Revista Brasileira de Entomologia*, v. 56, n. 3, p. 383-384, 2012.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). *Faostat*. 2015. Available at: <http://faostat3.fao.org/browse/rankings/countries_by_commodity/E>. Access on: Jan. 07, 2016.

GIOLO, F. P. et al. Seletividade de produtos fitossanitários utilizados na cultura do pessegueiro a *Trichogramma pretiosum* Riley, 1879 (Hymenoptera: Trichogrammatidae). *Ciência e Agrotecnologia*, v. 31, n. 5, p. 1396-1401, 2007.

GODOY, K. B. et al. Parasitismo em ovos de percevejos da soja *Euschistus heros* (Fabricius) e *Piezodorus guildinii*

(Westwood) (Hemiptera: Pentatomidae) em São Gabriel do Oeste, MS. *Ciência Rural*, v. 35, n. 2, p. 455-458, 2005.

GOULART, R. M. et al. Insecticide selectivity to two species of *Trichogramma* in three different hosts, as determined by IOBC/WPRS methodology. *Pest Management Science*, v. 68, n. 2, p. 240-244, 2012.

GUO, H. F. et al. Egg parasitism of rice stem borers in regions with different rice stem borer occurring patterns. *Chinese Journal of Biological Control*, v. 18, n. 1, p. 13-16, 2002.

GURR, G. M. et al. Parasitoids of the rice leaffolder *Cnaphalocrocis medinalis* and prospects for enhancing biological control with nectar plants. *Agricultural and Forest Entomology*, v. 14, n. 1, p. 1-12, 2012.

HASSAN, S. A. et al. A laboratory method to evaluate the side effects of plant protection products on *Trichogramma cacoeciae* Marchal (Hym., Trichogrammatidae). In: CANDOLFI, M. P. et al. (Eds.). *Guidelines to evaluate side-effects of plant protection products to non-target arthropods*. Gent: IOBC/WPRS, 2000. p. 107-119.

IDALGO, T. D. N. et al. Parasitismo de ovos de *Tibraca limbativentris* Stål (Hemiptera: Pentatomidae) em lavoura de arroz irrigado, Eldorado do Sul, RS. *Arquivos do Instituto Biológico*, v. 80, n. 4, p. 453-456, 2013.

KO, K. et al. Evaluation for potential *Trichogramma* (Hymenoptera: Trichogrammatidae) strains for control of the striped stem borer (Lepidoptera: Crambidae) in the Greater Mekong Subregion. *Journal of Economic Entomology*, v. 107, n. 3, p. 955-963, 2014.

KOPPEL, A. L. et al. Efficacy of selected insecticides against eggs of *Euschistus servus* and *Acrosternum hilare* (Hemiptera: Pentatomidae) and the egg parasitoid *Telenomus podisi* (Hymenoptera: Platygastridae). *Journal of Economic Entomology*, v. 104, n. 1, p. 137-142, 2011.

LAHM, G. P. et al. New and selective ryanodine receptor activators for insect control. *Bioorganic & Medicinal Chemistry*, v. 17, n. 12, p. 4127-4133, 2009.

LOU, Y. G. et al. Biological control of rice insect pests in China. *Biological Control*, v. 6, n. 1, p. 8-20, 2013.

MAGANO, D. A. et al. Efeitos secundários de herbicidas aplicados em soja sobre *Trichogramma pretiosum*. *Pesquisa Agropecuária Gaúcha*, v. 19, n. 1/2, p. 49-56, 2013.

MAGANO, D. A. et al. Evaluating the selectivity of registered fungicides for soybean against *Trichogramma pretiosum* Riley, 1879 (Hymenoptera: Trichogrammatidae). *African Journal of Agricultural Research*, v. 10, n. 40, p. 3825-3831, 2015.

MARUYAMA, W. I. et al. Parasitoides de ovos de percevejos (Hemiptera: Heteroptera) em plantas daninhas. *Revista Ceres*, v. 49, n. 284, p. 453-459, 2002.

MOURA, A. P. et al. Selectivity evaluation of insecticides used to control tomato pests to *Trichogramma pretiosum*. *BioControl*, v. 51, n. 6, p. 769-778, 2006.

OLIVEIRA, H. N. de et al. Seletividade de inseticidas utilizados na cana-de-açúcar a adultos de *Trichogramma galloi* Zucchi (Hymenoptera: Trichogrammatidae). *Bioscience Journal*, v. 29, n. 5, p. 1267-1274, 2013.

PACHECO, D. J. P.; CORRÊA-FERREIRA, B. S. Parasitismo de *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae) em populações de percevejos pragas da soja. *Anais da Sociedade Entomológica do Brasil*, v. 29, n. 2, p. 295-302, 2000.

PARRA, J. R. P. Técnicas de criação de *Anagasta kuehniella*, hospedeiro alternativo para produção de *Trichogramma*. In: PARRA, J. R. P.; ZUCCHI, R. A. (Eds.). *Trichogramma e o controle biológico aplicado*. Piracicaba: Fealq, 1997. p. 121-150.

PAZINI, J. de B. et al. Geoestatística aplicada ao estudo da distribuição espacial de *Tibraca limbativentris* em arrozal irrigado por inundação. *Ciência Rural*, v. 45, n. 6, p. 1006-1012, 2015.

PERES, W. A. A.; CORRÊA-FERREIRA, B. S. Methodology of mass multiplication of *Telenomus podisi* Ash. and *Trissolcus basalis* (Woll.) (Hymenoptera: Platygastridae) on eggs of *Euschistus heros* (Fab.) (Hemiptera: Pentatomidae). *Neotropical Entomology*, v. 33, n. 4, p. 457-462, 2004.

POTRICH, M. et al. Seletividade de *Beauveria bassiana* e *Metarhizium anisopliae* a *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae). *Neotropical Entomology*, v. 38, n. 6, p. 822-826, 2009.

PREETHA, G. et al. Toxicity of selected insecticides to *Trichogramma chilonis*: assessing their safety in the rice ecosystem. *Phytoparasitica*, v. 37, n. 3, p. 209-215, 2009.

QUERINO, R. B.; ZUCCHI, R. A. Caracterização morfológica de dez espécies de *Trichogramma* (Hymenoptera: Trichogrammatidae) registradas na América do Sul. *Neotropical Entomology*, v. 32, n. 4, p. 597-613, 2003.

R DEVELOPMENT CORE TEAM. *R*: a language and environment for statistical computing. rev. 3.2.0. Vienna: R Foundation for Statistical Computing, 2015.

RANI, P. U. et al. Kairomones extracted from rice yellow stem borer and their influence on egg parasitization by *Trichogramma japonicum* Ashmead. *Journal of Chemical Ecology*, v. 33, n. 1, p. 59-73, 2007.

REYNOLDS, S. E. The cuticule, growth regulators and moulting in insects: the essential background to the action of acylurea insecticides. *Pesticide Science*, v. 20, n. 2, p. 131-146, 1987.

RIFFEL, C. T. et al. Primeiro relato de ocorrência de *Telenomus podisi* (Ashmead) e *Trissolcus urichi* (Crawford) (Hymenoptera : Platygastridae) como parasitoides de ovos do percevejo-do-colmo-do-arroz, *Tibraca limbativentris* (Stål) (Hemiptera: Pentatomidae), em Santa Catarina. *Neotropical Entomology*, v. 39, n. 3, p. 447-448, 2010.

SILVA, C. C. et al. *Euschistus heros* mass rearing technique for the multiplication of *Telenomus podisi*. *Pesquisa Agropecuária Brasileira*, v. 43, n. 5, p. 575-580, 2008.

SOCIEDADE SUL-BRASILEIRA DE ARROZ IRRIGADO (Sosbai). *Arroz irrigado*: recomendações técnicas da pesquisa para o Sul do Brasil. Santa Maria: Sosbai, 2014.

STECCA, C. dos S. et al. Insecticide selectivity for *Doru lineare* (Dermaptera: Forficulidae). *Revista Brasileira de Milho e Sorgo*, v. 13, n. 1, p. 107-115, 2014.

STEFANELLO JÚNIOR, G. J. et al. Efeito de inseticidas usados na cultura do milho sobre a capacidade de parasitismo de *Trichogramma pretiosum* Riley, 1879 (Hymenoptera: Trichogrammatidae). *Arquivos do Instituto Biológico*, v. 75, n. 2, p. 187-194, 2008a.

STEFANELLO JÚNIOR, G. J. et al. Seletividade de herbicidas registrados para a cultura do milho a adultos de *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). *Planta Daninha*, v. 26, n. 2, p. 343-351, 2008b.

STEFANELLO JÚNIOR, G. J. et al. Persistência de agrotóxicos utilizados na cultura do milho ao parasitoide *Trichogramma pretiosum* Riley, 1879 (Hymenoptera: Trichogrammatidae). *Ciência Rural*, v. 42, n. 1, p. 17-23, 2012.

STEFANELLO JÚNIOR, G. J. et al. Seletividade de herbicidas registrados para a cultura do milho aos estádios imaturos de *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). *Planta Daninha*, v. 29, special n., p. 1069-1077, 2011.

SUDHANAN, M. E. et al. Toxicity of flubendiamide 20 WG against egg parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) under laboratory conditions. *Journal of Biological Control*, v. 28, n. 3, p. 147-150, 2014.

UMA, S. et al. Acute contact toxicity of selected conventional and novel insecticides to *Trichogramma japonicum* Ashmead (Hymenoptera: Trichogrammatidae). *Journal of Biopesticides*, v. 7, n. 1, p. 133-136, 2014.