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Physiological selectivity of insecticides to adult of *Doru luteipes* (Scudder, 1876) (Dermaptera: Forficulidae)[1]

Seletividade fisiológica de inseticidas para adultos de *Doru luteipes* (Scudder, 1876) (Dermaptera: Forficulidae)

Ana Carolina Maciel Redoan[2]*, Geraldo Andrade Carvalho[3], Ivan Cruz[4], Maria de Lourdes Corrêa Figueiredo[4] e Rafael Braga da Silva[4]

ABSTRACT - *Doru luteipes* (SCUDDER, 1876) is considered one of the best natural enemies of the fall armyworm *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae), feeding on their eggs and small caterpillars. For its conservation it is necessary to use selective insecticides to *S. frugiperda* and harmless to the predator. Therefore, objective of the present work was to evaluate the toxicity of insecticides registered to control of *S. frugiperda*. It was conducted bioassays with *D. luteipes* adults treated with insecticides directly by exposure to residues of compounds applied on glass plates and the consumption of eggs of *S. frugiperda* contaminated and offered each one, 24 and 48 hours after treatment. The insecticides were classified according to indices proposed by IOBC/WPRS. For adults *D. luteipes* treated directly with insecticides, triflumuron was harmless (class 1); chlorfenapyr and etofenprox as slightly harmful (class 2) teflubenzuron/α-cypermethrin and spinosad moderately harmful (class 3) and thiamethoxan/λ-cyhalothrin harmful (class 4). In bioassay exposure of *D. luteipes* residues of insecticides applied to glass plates, all products were harmful to the predator, except triflumuron which was considered slightly harmful. The survival of adults after consumption of contaminated eggs was 46.7% for the insecticide tiametoxam/λ-cialotrina considered slightly harmful to the predator. The other insecticides were innocuous. Due to the low toxicity presented by the triflumuron to the *D. luteipes* adults, this compound can be recommended in programs aimed at integrated pest management the preservation of this natural enemy. All other products must be evaluated in greenhouse and field to prove its toxicity.

Key words: *Zea mays*. Pest. Predator. Pesticides. Toxicity.

RESUMO - *Doru luteipes* (SCUDDER, 1876) é um dos principais inimigos naturais da *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae), alimentando-se de seus ovos e lagartas pequenas. Para sua conservação é necessária a utilização de inseticidas seletivos a *S. frugiperda* e inócuos ao predador. Assim, o objetivo deste trabalho foi avaliar a toxicidade de inseticidas registrados para o controle de *S. frugiperda*. Foram conduzidos bioensaios com adultos de *D. luteipes* tratados diretamente com os inseticidas, exposição aos resíduos dos compostos aplicados em placas de vidro e consumo de ovos de *S. frugiperda* contaminados e ofertados uma, 24 e 48 horas após o tratamento. Os inseticidas foram classificados segundo índices propostos pela IOBC/WPRS. Para os adultos de *D. luteipes* tratados diretamente com os inseticidas, triflumurom foi inócuo (classe 1); clorfenapir e etofemproxi levemente nocivos (classe 2); teflubenzurom/α-cipermetrina e espinosade moderadamente nocivos (classe 3) e tiametoxam/λ-cialotrina nocivo (classe 4). No bioensaio de exposição de *D. luteipes* aos resíduos dos inseticidas aplicados em placas de vidro, todos os produtos foram nocivos ao predador, exceto triflumurom que foi levemente nocivo. A sobrevivência de adultos após o consumo de ovos contaminados com tiametoxam/λ-cialotrina foi de 46,7% (levemente nocivo ao predador); os demais inseticidas foram inócuos. Devido à baixa toxicidade do triflumurom a adultos do predador, este composto pode ser recomendado em programas de manejo integrado de pragas visando a preservação dessa espécie de inimigo natural. Os demais produtos devem ser avaliados em casa de vegetação e campo para comprovação de sua toxicidade.

Palavras-chave: *Zea mays*. Peste. Predador. Pesticidas. Toxicidade.

INTRODUCTION

Among the several factors that affect maize (*Zea mays* L.) productivity, the fall armyworm *Spodoptera frugiperda* (J. E. SMITH, 1797) (Lepidoptera: Noctuidae) is considered the main pest of this crop in Brazil, and one of the most important in the Americas, which can cause losses of more than 50% (FIGUEIREDO; MARTINS-DIAS; CRUZ, 2006). The control of *S. frugiperda* in maize has been done mostly by using chemicals applied immediately after its detection in the field and generally causes biological unbalances and other negative environmental impacts (CRUZ; VIANA; WAQUIL, 2002).

In maize, natural enemies that act in the early stages of pest development, thus avoiding significant damages to plants, are the most important. This is the case, for example, of *Doru luteipes* (SCUDDER, 1876) (Dermaptera: Forficulidae). This predator has been considered of great potential as a biological control agent of maize pests, such as *S. frugiperda*, *Helicoverpa zea* (BODDIE, 1850) (Lepidoptera: Noctuidae) and aphids (REIS; OLIVEIRA; CRUZ, 1988; CRUZ; ALVARENGA; FIGUEIREDO, 1995).

The earwigs are considered voracious predators because they have high ability to attack and feed on different preys, particularly eggs and immature stages of insects of the orders Lepidoptera, Hemiptera, Coleoptera and Diptera. And the presence of *D. luteipes* in 80% of the maize plant is sufficient to maintain the fall armyworm under control, below the economic injury level (CRUZ; OLIVEIRA, 1997). Thus, is necessary to integrate the biological control of this predator and other control methods, as the chemical (PASINI; PARRA; LOPES, 2007).

The use of selective products minimizes exposure of natural enemies and at the same time, controls the pests species. It is necessary to integrate the biological control of this predator and other control methods, as the chemical. Since the use of chemicals must be used only when all the control alternatives had been extinguished and in an emergency way, by means of selective products (BOLLER *et al.,* 2004). Reis, Oliveira and Cruz (1988), Faleiro *et al.* (1995) and Simões, Cruz and Salgado (1998) studied the selectivity of insecticides used in maize to control nymphs and adults of *D. luteipes* and concluded that the adult predator was more tolerant to the compounds than nymphs, mainly to the pyrethroid insecticides permethrin and deltamethrin.

Zotti *et al.* (2010) observed that the survival of adults of *Doru lineare* (ESCHSCHOLTZ, 1822) (Dermaptera: Forficulidae) after ingestion eggs of *S. frugiperda* contaminated with insecticides was reduced to Certero® with means of 50% and Engeo Pleno® with 100% mortality.

In this context, the objective of this study was to evaluate the selectivity of six insecticides registered to the control of *S. frugiperda* in maize, in the higher doses recommended by manufacturers, for adults of the predator *D. luteipes*.

MATERIAL AND METHODS

The experiments were carried out at the insect rearing laboratory (Laboratório de Criação de Insetos - LACRI) of the "Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS)", from "Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA)" in Sete Lagoas, Minas Gerais State, Brazil.

Eggs, nymphs and adults of *D. luteipes* were collected in an area with the 'BRS1031' maize, cultivated in an organic system and maintained in laboratory at 25 ± 2 °C, relative humidity $70 \pm 10\%$ and 12 hours photophase for creation and subsequent use in experiments.

For the creation of the predators in the laboratory couples of *D. luteipes* were placed in cages made from PVC pipe measuring 30 cm diameter and 50 cm high, which was capped at both ends with a 2 cm PVC ring closed with a nylon mesh 0.5 mm diameter. Inside each cage 10 central buds of maize (cartridges) were placed to be used as oviposition substrate and shelter for insects. The insects were fed *ad libitum* on unviable eggs of *S. frugiperda* and a diet based on cat food (CRUZ, 2009).

Trademarks and dosages of active ingredients were: Certero® (triflumuron - 48 g a.i ha⁻¹), Engeo-Pleno® (thiamethoxan + λ-cyhalothrin - 32,5 + 26.5 g a.i ha⁻¹, respectively), Imunit® (teflubenzuron + α-cypermethrin - 12.7 + 12.7 g a.i ha⁻¹, respectively), Pirate® (chlorfenapyr - 180 g a.i ha⁻¹), Safety® (etofenprox - 30 g a.i ha⁻¹) and Tracer® (spinosad 48 g a.i ha⁻¹). The control treatment was only water.

The compounds were diluted in 282 liters of water/ha. After application of each product, pulverizer and spray nozzle were washed with water and then with acetone to remove residues of each compound. Insecticides were applied using a CO_2 pressurized sprayer with a fan type nozzle 80.03, adjusted to a pressure of 2.6 lb/pol², coupled to a treadmill at constant speed of 6.2 km/h according to the methodology by Simões, Cruz e Salgado (1998).

Effects of insecticides directly applied on adults of *D. luteipes*

Couples were placed in Petri dishes with 18 cm diameter and 1.5 cm high and submitted to insecticides spraying in a treadmill, as previously mentioned. Each treated couple was placed in a plastic cup inserted on Styrofoam tray which was maintained in laboratory at 25 ± 2 °C, relative humidity $70 \pm 10\%$ and 12 hours

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photophase. The insects were fed *ad libitum* on unviable eggs of *S. frugiperda.*The number of dead insects was evaluated every 24 hours for 15 days after contamination of the adults with insecticides. Five replications with 24 insects were done for each treatment.

Effect of residual contact of insecticides on adults of *D. luteipes*

Insecticides applications were done in arenas comprised by capped Petri dishes measuring 18 cm diameter and 1.5 cm high under treadmill, which was maintained in laboratory at 25 ± 2 °C, relative humidity 70 ± 10% and 12 hours photophase. After elimination of the excess of moisture couples of the predator were released into the arenas, being in constant contact with the dry film of each insecticide throughout the evaluation period. The number of dead adults was recorded every 24 hours during the 15 days of exposition of the insects to the residues of compounds. Oviposition capacity and egg viability of surviving couples were assessed. The insects were fed *ad libitum* on unviable eggs of *S. frugiperda*. Each treatment consisted of five replications with six couples.

Effect of the ingestion of food contaminated by insecticides on adults of *D. luteipes*

Ovipositions of about 50 eggs of *S. frugiperda* 24 hours old were placed on Petri dishes covered with aluminum paper and maintained under refrigeration at 8 °C for 48 hours to make eggs unfeasible. After this period, each oviposition was fixed through an entomological pin on a styrofoam plate 36 cm long by 24 cm wide and subjected to the spraying of insecticides as earlier mentioned. After the applications, part of the *S. frugiperda* eggs unfeasible after one hour was offered to adults of the predator previously individualized in 50 mL plastic cups fixed in styrofoam trays. Other offerings were done at 24 and 48 hours after pulverization.

Survival of adults up to 15 days (360 hours) after the beginning of exposure to *S. frugiperda* eggs treated with insecticides was evaluated. Oviposition capacity and egg viability of surviving couples were assessed. Each treatment comprised five replications with six couples.

Data from these experiments were analyzed by one-way Analysis of Variance through the SISVAR (FERREIRA, 2007) and treatment means were compared with the Scott-Knott test (P = 0.05) (SCOTT; KNOTT, 1974); Burr- Foster Q and Shapiro-Wilk W tests were used to test equality of variance and normality of the data, following description found in Anderson and McLean (1974).

The insecticides were classified using toxicity indices proposed by IOBC/WPRS (HASSAN *et al.*, 1985), according to the mortality means, in: 1) harmless (< 30%); 2) slightly harmful (30-79%); 3) moderately harmful (80-99%) and 4) harmful (>99%).

RESULTS AND DISCUSSION

Effects of insecticides directly applied on adults of *D. luteipes*

For couples of *D. luteipes* directly treated with insecticides, triflumuron was the product responsible for lower mortality, causing the death of only 13.3% of males and 5% of females at 360 hours after start exposure (HASE), being considered harmless (Table 1).

The selectivity of triflumuron to the predator in the adult stage was possibly due to the mode of action, since belongs to the chemical group of benzoilureas, chitin synthesis inhibitors, which act mainly as ovicidal and larvicidal (OMOTO, 2000). The ovicidal and larvicidal actions were evaluated by Simões, Cruz e Salgado (1998), where eggs and nymphs of *D. luteipes* were treated through triflumuron pulverization (25 g a.i ha^{-1}), and mortality of 78% of eggs and 69.6% of nymphs was observed. Tonet (1995) determined the impact of insecticides used on soybeans on *D. lineare*, triflumuron, the product was considered of low toxicity (mortality 21-40%) and was considered selective diflubenzuron (up to 20% mortality).

Mortality of males and females by thiamethoxan/λ-cyhalothrin was 97.5% in the first 24 HASE, and 100% at 48 HASE proving to be harmful (class 4). Teflubenzuron/α-cypermethrin caused high mortality at 24 HASE, with 85% for males and 86.7% for females. At 360 HASE the means were 95% and 93.3%, respectively. Therefore, it was classified as moderately harmful (Table 1).

The high mortality observed in the present study at the first assessment for thiamethoxan/λ-cyhalothrin and teflubenzuron/α-cypermethrin may have occurred because of the combination of two active ingredients with different mechanisms of action (neonicotinoid + pyrethroid and pyrethroid + benzoilureia, respectively). With different active ingredients and acting simultaneously on the same insect, the toxicity of the product can be significantly increased (RIGITANO; CARVALHO, 2001).

Chlorfenapyr caused mortality of about 15.8% for males and 16.7% for females in the first 24 HASE. At the next 48 HASE mortality increased to 31.7% and 24.2%, reaching 51.7% and 40% at 360 HASE for males and females, respectively, and was considered slightly harmful (class 2) (Table 1).

Few studies are known concerning the selectivity of chlorfenapyr to natural enemies, however Leite *et al.* (2010) evaluated its action on third instar

larvae and adults of the predator *Cycloneda sanguinea* (Linnaeus) (Coleoptera: Coccinellidae). Evaluations were accomplished at one, 12; 23 and 35 days after chlorfenapyr pulverization (240 SC - 160 g a.i ha⁻¹), and high toxicity was observed with 100% mortality of larvae and adults of this predator. This compound is an ATP synthesis inhibitor which can act by contact or ingestion, causing the uncoupling of oxidative phosphorylation reactions, so that mitochondria fails to produce ATP, stopping vital functions of the cell, causing insect death. Unlike neurotoxic insecticides, the action of chlorfenapyr is not immediate, and death occurs after the depletion of the energy reserves of the insect (OMOTO, 2000).

Etofenprox caused 37% mortality for males and 42.5% for females, reaching 57.5% and 53.3% for males and females, respectively, at 48 HASE, being classified as slightly harmful. Spinosad showed a gradual increase in mortality of *D. luteipes*, reaching 82.5% for males and 64.2 for females of the predator, being classified as moderately harmful to males and slightly harmful to females at 360 HASE (Table 1).

For insects directly treated through spraying of insecticides it was observed that 70.8% of females laid eggs after treatment with triflumuron; nevertheless, only 8.6% of eggs were viable and 60% of nymphs from these couples reached the fourth instar (Table 2).

Decrease in number of ovipositions and viability of eggs and nymphs was also observed for chlorfenapyr, etofenproxi and spinosad, and after the treatment with spinosad only 45.8% of females laid eggs, which presented only 10.3% viability. Nymphs were also affected by chlorfenapyr; 70% survived the first instar and 63.3% reached the fourth instar. Etofenproxi presented the highest mortality throughout the development of nymphs, and 90% survived the first instar but only 50% reached the fourth instar. Due to the high toxicity of thiamethoxan/λ-cyhalothrin and teflubenzuron/α-cypermethrin, no live insects enough to evaluate the sublethal effects were found (Table 2).

Negative effects on fecundity and fertility of some insect species caused by chemical compounds were also found by other authors. Ávila and Nakano (1999) evaluate the toxic effects of the growth regulator lufenurom (0.33 g a.i ha) on adult fecundity and egg viability of *Diabrotica speciosa* (Germar, 1824) (Coleoptera: Chrysomelidae) in the laboratory. The authors say the low number of eggs (177.5) as well

Table 1 - Mortality (%) (± SE) of adults (males and females) of *Doru luteipes* (Dermaptera: Forficulidae) after being treated with insecticides at different time intervals and classes of toxicity of the compounds evaluated

Treatment	Mortality (%) of males D. *luteipes*[1]					
	24 h	48 h	72 h	168 h	360 h	C[2]
Water	0.0±0.0 Da	0.0±0.0 Da	0.0±0.0 Ca	0.0±0.0 Ca	0.0±0.0 Ca	-
Triflumurom	0.0± 0.0 Db	3.3±2.4 Db	4.2±3.2 Cb	12.5±5.3 Ca	13.3±5.0 Ca	1
Thiamethoxan/λ-cyhalothrin	97.5±1.7 Aa	100.0±0.0 Aa	-	-	-	4
Teflubenzuron/α-cypermethrin	85.0±7.8 Aa	88.3±5.2 Aa	91.7±3.7 Aa	92.5±7.5 Aa	95.0±2.4 Aa	3
Chlorfenapyr	15.8± 4.0 Cc	31.7±5.4 Cb	50.8±3.6 Ba	51.7±3.4 Ba	51.7±3.4 Ba	2
Etofenproxi	37.5± 7.6 Bb	45.8±8.0 Bb	51.7±6,3 Ba	57.5±8.3 Ba	57.5±8.3 Ba	2
Spinosad	29.2±5.4 Bc	55.8±8.4 Bb	69.2±8.8 Bb	80.0±4.8 Ba	82.5±4.8 Aa	3
Treatment	Mortality (%) of females D. *luteipes*[1]					
	24 h	48 h	72 h	168 h	360 h	C[2]
Water	0.0±0.0 Ca	0.0±0.0 Da	0.0±0.0 Da	0.0±0.0 Da	0.0±0.0 Da	-
Triflumurom	0.0±0.0 Ca	0.8±0.8 Dc	1.7±1.0 Db	4.2±1.3 Da	5.0±0.8 Da	1
Thiamethoxan/λ-cyhalothrin	97.5±1.7 Aa	100.0±0.0 Aa	-	-	-	4
Teflubenzuron/α-cypermethrin	86.7±7.1 Aa	90.8±4.8 Aa	92.5±3.8 Aa	93.3±4.1 Aa	93.3±4.1 Aa	3
Chlorfenapyr	16.7±6.2 Cb	24.2±5.7 Cb	24.2±5.7 Cb	39.2±6.5 Ca	40.0±6.3 Ca	2
Etofenproxi	42.5±9.3 Ba	50.0±7.8 Ba	54.2±17.9 Ba	53.3±8.4 Ba	53.3±8.4 Ba	2
Spinosad	22.5±6.4 Cc	36.7±2.4 Bb	52.5±6.8 Ba	63.3±6.3 Ba	64.2±6.0 Ba	2

[1]Mean followed by the same letter, in uppercase or lowercase column lines for each insecticide, do not differ by Scott-Knott test (SCOTT; KNOTT, 1974) at 5% significance level. [2]Classe toxicity of insecticides second IOBC / WPRS (HASSAN *et al.*, 1985)

Table 2 - Percentage of female *Doru luteipes* (Dermaptera: Forficulidae) postures, egg viability (%) and survival of nymphs from directly couples treated with insecticides

Treatment	Females posture	Egg Viability	Survival of nymphs			
			1° instar	2° instar	3° instar	4°instar
Water	100±0.0 A	90.3±3.1 A	100±0.0 Aa	100±0.0 Aa	100±0.0 Aa	100±0.0 Aa
Triflumurom	70.8±18.7 A	8.6±2.9 B	76.7±23.2 Aa	66.7±20.0 Ba	60±15.5 Ba	60±15.5 Ba
Thiamethoxan/λ-cyhalothrin	*	*	*	*	*	*
Teflubenzuron/α-cypermethrin	*	*	*	*	*	*
Clofenapir	58.3±20.1 B	11.36±3.9 B	70±30.5 Aa	63.3±27.7 Ba	63.3±27.7 Ba	63.3±27.7 Ba
Etofenproxi	62.5±20.1 B	16.2±5.8 B	90±10.18 Aa	90±10.0 Aa	56.7±10.1 Bb	50±11.7 Bb
Spinosad	45.8±20.0 C	10.3±3.0 B	73.3±27.1 Aa	56.7±23.7 Ba	56.7±23.7 Ba	56.6±23.7 Ba

[1]Mean followed by the same letter, in uppercase or lowercase column lines for each insecticide, do not differ by Scott-Knott test (SCOTT; KNOTT, 1974) at 5% significance.* No live insects for evaluation of effect residual contact of insecticides on adults of *D. luteipes*

as their low viability (19.8%) obtained from couples who have ingested the insecticide can be explained by trans ovarian transmission, affecting embryonic development and preventing larvae hatching.

Effect of residual contact of insecticides on adults of *D. luteipes*

Triflumurom did not cause effect on predators in the first 24 hours, presenting mortality of 33% for males and 26.7% for females at 48 HASE. From 72 HASE, mortality remained at 46% for female but increased from 46% to 53.3% for males at 360 HASE and even so was considered slightly harmful (Table 3).

Teflubenzuron/α-cypermethrin and thiamethoxan/λ-cyhalothrin presented toxicity of 66.7% and 60% for males and 56.6% and 66.7% for females, respectively, at 24 HASE. At 48 HASE, 100% of male was killed, so the products were harmful (class 4) to the predator. For females, the same products caused 100% and 93.3% mortality, respectively, considered harmful. Chlorfenapyr caused 100% mortality for males at 24 HASE. For females, mortality was 60% at 24 HASE, 70% at 48 HASE and 100% at 72 HASE. Etofenprox caused low mortality rates for males and females (3.3% and 0%, respectively) at 24 HASE, however, caused the deaths of 100% of males at 48 HASE and females at 72 HASE, and for this reason was in class 4 (harmful). Spinosad caused 93.3% mortality of males at 360 HASE and 100% of females at 72 HASE, considered slightly harmful (Table 3).

In general, all products were more toxic to the predator when applied to a surface rather than when

applied directly to adults. This is due to the fact that the tarsal contact method where it is estimated a lethal time to the insects absorb insecticide throughout the test period. Rajashekar, Rao and Shivanandappa (2012) demonstrated experimentally that some insecticides are most effective when in contact with the tarsi of insects. The insecticidal activity of some molecules is lost by hydrolysis, and various sugars, which modifies the toxic response, demonstrating that insecticidal activity can occur through sites located in tarsi.

According to Maia, Busoli and Delabie (2001), the longer the period of exposure of insects to chemicals, the greater the probability of intoxication of the target organism. Another possible explanation for the high mortality rates observed in the present study is related to the behavior of the Dermaptera, since they have the characteristic of constant cleaning of the body using the mouth parts (LANGSTON; POWELL, 1975), which increases even more the chances of contamination by the chemicals tested. The lower rate of penetration of insecticides when applied directly to adult insects may be due to the chemical composition and the greater thickness of the exoskeleton. But when the insect is exposed to the product for a long period, small amounts will penetrate the insect's body and can be lethal slowly in 360 HASE (LEITE *et al.*, 1998).

It was not possible to evaluate the sublethal effects of thiamethoxan/λ-cyhalothrin, teflubenzuron/α-cypermethrin, chlorfenapyr, etofenprox and spinosad due to the high toxicity presented. However, triflumuron was slightly harmful but no ovipositing females were observed in the period of evaluation.

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Table 3 - Cumulative mortality (%) (±SE) of adult *Doru luteipes* (Dermaptera: Forficulidae) after initial exposure of insects to residues of the compounds at different time intervals and classes of toxicity of the insecticides evaluated

Treatment	Mortality of male *D. luteipes*[1]					
	24 h	48 h	72 h	168 h	360 h	C[2]
Water	0.0± 0.0 Ca	0.0± 0.0 Ca	0.0± 0.0 Ca	0.0± 0.0 Ca	0.0± 0.0 Ca	-
Triflumurom	0.0± 0.0 Cc	33.3±21.1 Bb	46.7±16.2 Ba	46.7±16.2 Ba	53.3±13.3 Ba	2
Thiamethoxan/λ-cyhalothrin	66.7±14.9 Ab	100.0±0.0 Aa	-	-	-	4
Teflubenzuron/α-cypermethrin	60.0±10.0 Ab	100.0±0.0 Aa	-	-	-	4
Chlorfenapyr	100.0±0.0 A	-	-	-	-	4
Etofenproxi	3.3±3.3 Cb	100.0±0.0 Aa	-	-	-	4
Spinosad	36.7±18.6 Bb	70.0±13.3 Aa	93.3±6 Aa	93.3±6Aa	93.3±6 Aa	3

Treatment	Mortality of female *D. luteipes*[1]					
	24 h	48 h	72 h	168 h	360 h	C[2]
Water	0.0± 0.0 Ca	0.0± 0.0 Da	0.0± 0.0 Ca	0.0± 0.0 Ba	0.0± 0.0 Ba	-
Triflumurom	0.0± 0.0 Cc	26.7±18.7 Cb	46.7±14.3 Ba	46.7±14.3 Aa	46.7±14.3 Aa	2
Thiamethoxan/λ-cyhalothrin	56.7±12.5 Ab	100.0±0.0 Aa	-	-	-	4
Teflubenzuron/α-cypermethrin	66.7±11.8 Ab	93.3±6.7 Aa	100.0±0.0 Aa	-	-	4
Chlorfenapyr	60.0±10.0 Ab	70.0±9.7 Ab	100.0±0.0 Aa	-	-	4
Etofenproxi	0.0± 0.0 Cc	63.3±12.2 Bb	100.0±0.0 Aa	-	-	4
Spinosad	36.7± 18.6 Bb	76.7±10.0 Aa	100.0±0.0 Aa	-	-	4

[2]Classe toxicity of insecticides second IOBC / WPRS (HASSAN *et al.*, 1985).[1]Mean followed by the same letter, in uppercase or lowercase column lines for each insecticide, do not differ by Scott-Knott test (SCOTT; KNOTT, 1974) at 5% significance

Effect of the ingestion of food contaminated by insecticides on adults of *D. luteipes*

For couples that received eggs as food immediately after the chemical treatment the survival rate was higher than 80% in all treatments thus classified as class 1 (harmless), except thiamethoxan/λ-cyhalothrin with means of survival for males 36.7% and 43.4 for females being included in class 2 (slightly toxic) (Table 4).

These results corroborate those found by Simões, Cruz and Salgado (1998), in which adults of *D. luteipes* were fed eggs of *S. frugiperda* treated with the insecticides triflumuron, permethrin, diflubenzuron and λ-cyhalothrin, with means of survival 94; 97; 97 and 93%, respectively. Similar results to the presented in this study were also reported by Bacci *et al.* (2001), where the pyrethroid permethrin was highly selective for adults of *D. luteipes*. Michereff Filho *et al.* (2002) evaluating the effect of deltamethrin on adults of this predator observed that the compound was harmless.

For insects that ingested eggs of *S. frugiperda* 24 and 48 hours after treatment with insecticides, no death was caused by triflumurom, differently of the other treatments (Table 4). Chlorfenapyr, etofenprox

and spinosad were harmless, with mortalities of 10%, 0% and 10% for males and 10.1, 0 and 26.7% for females, respectively. Thiamethoxan/λ-cyhalothrin was slightly harmful, presenting mortality rate of 53.3% and teflubenzuron/α-cypermethrin was harmless with mortality lower than 30% for males and females of *D. luteipes* that ingested eggs of *S. frugiperda* 48 hours after treated with insecticides (Table 4).

Different result was obtained by Farias *et al.* (2006), evaluating the effects at field of thiamethoxan + λ-cyhalothrin (Enge Max - 21.2 g a.i ha^{-1}) on the predators *Doru lineare* (ESCHSCHOLTZ, 1822) (Dermaptera: Forficulidae) and *Chrysoperla* sp. (Neuroptera: Chrysopidae) in soybean. The authors concluded that the product reduced the population of these enemies in more than 90%. Cisneros *et al.* (2002) evaluated the effect of the insecticide spinosad on *Doru taeniatum* (DOHRN, 1847) (Dermaptera: Forficulidae) and observed that mortality of the predator soon after consume treated larvae of *S. frugiperda* was 17% and at 72 hours reached 72%.

The divergence of results regarding action of some compounds on insects may be due to bio-ecological factors intrinsic to each species and also to

Table 4 - Percent survival of adult *Doru luteipes* (Dermaptera: Forficulidae) after the consumption of eggs of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) were treated with insecticides and provided to the predator after one, 24 and 48 hours of classes and toxicity of the compounds evaluated

Treatment	Survival of male *D. luteipes*[1]				Survival of female *D. luteipes*[1]			
	1 h	24 h	48 h	C[2]	1 h	24 h	48 h	C[2]
Water	100.0±.0 Aa	100.0±0.0 Aa	100.0±0.0 Aa	-	100.0±0.0 Aa	100.0±0.0 Aa	100.0±0.0 Aa	-
Triflumurom	93.3±4.1 Aa	100.0±0.0 Aa	100.0±0.0 Aa	1	80.0±6.25 Aa	100.0±0.0 Aa	100.0±0.0 Aa	1
Thiamethoxan/λ-cyhalothrin	43.3±8.0 Ba	21.7±9.7 Cb	46.7±9.7 Ba	2	36.7±8.2 Ba	43.7±8.5 Ba	36.7±9.7 Ba	2
Teflubenzuron/α-ypermethrin	66.7±5.3 Ba	69.9±3.3 Ba	86.7±3.3 Aa	1	80.0±6.3 Aa	73.3±6.3 Aa	86.7±3.3 Aa	1
Chlorfenapyr	83.3±10.6 Aa	90.0±4.1 Aa	90.0±4.1 Aa	1	90.0±6.7 Aa	93.3±4.1 Aa	89.9±4.1 Aa	1
Etofenproxi	96.7±3.3 Aa	100.0±0.0 Aa	100.0±0.0 Aa	1	96.7±3.3 Aa	96.7±3.3 Aa	100.0±0.0 Aa	1
Spinosad	86.7± 8.2 Aa	90.0±6.7 Aa	90.0±6.7 Aa	1	86.7±6.3 Aa	90.0±4.1 Aa	73.3±11.0 Aa	1

[1]Mean followed by the same letter, in uppercase or lowercase column lines for each insecticide, do not differ by Scott-Knott test (SCOTT; KNOTT, 1974) at 5% significance.[2]Classe toxicity of insecticides second IOBC / WPRS (HASSAN *et al.*, 1985)

the differences in concentrations of the commercial product used and even the characteristic of the eggs of *S. frugiperda*, such as permeability of corium and adjacent layers, what may or not facilitate the penetration of the products (MANZONI *et al.*, 2007).

In general, the survival of adults of the predator after ingestion of eggs of *S. frugiperda* at one, 24 and 48 hours after treatment was not affected by triflumuron, chlorfenapyr, etofenprox and spinosad, which were selective and classified as harmless. Males that ingested eggs of *S. frugiperda* 24 hours after treated with thiamethoxan/λ-cyhalothrin presented survival rate of only 21.7% and females that consumed eggs treated with teflubenzuron/α-cypermethrin showed survival of 73.3%.

The high survival rates of adults of the predator observed in this study can be due to the action of insecticides in the body of insects, since the ingested product can undergo the action of several enzymes in the digestive system and Malpighi tubules, making the molecule non-toxic or less toxic to the body (YU, 2002).

Insecticide metabolism can be complex and occurs in all insects, regardless of insecticide resistance status, and is likely to involve a multistep pathway. For many insecticides, different metabolic breakdown products are possible. Although there is evidence of insecticide metabolism in other tissues there is building evidence that the key tissues for the metabolism of most compounds are the midgut, the Malpighian tubules and the fat body. Recent large-scale transcript sequencing projects and microarray studies identify a large number of detoxification genes expressed in these tissues (PERRY; BATTERHAM; DABERR, 2011).

For couples who ingested eggs of *S. frugiperda* one and 24 hours after treatment with triflumuron, chlorfenapyr and etofenprox the percentage of ovipositing females were 25, 25, 29 and 20, 25, 37%, respectively. Females that fed eggs of *S. frugiperda* 48 hours after treatment presented similar results to the females that fed eggs one hour after treatment. For treatments with thiamethoxan/λ-cyhalothrin, teflubenzuron/α-cypermethrin and spinosad no ovipositing females were observed (Table 5).

Despite low mortality of *D. luteipes* after ingestion of treated eggs of *S. frugiperda*, it was observed that insecticides negatively affected oviposition and egg viability. Many eggs were dry and with dark color after two days, without formation of embryo. Among the evaluated compounds, only triflumuron allowed the birth of nymphs, with mean of 7.6% (Table 5).

The ovicide mode of action of lufenuron to *Podisus nigrispinus* (Heteroptera: Pentatomidae) was reported by Evangelista Júnior *et al.* (2002). These authors observed that the eggs after three to four days of oviposition were reddish due to embryonic development, but being interrupted by the insecticide they become dark and withered with the death of the embryo.

The transovarian action of tebufenozide (84 g a.i ha^{-1}) was reported by Pratissoli *et al.* (2003) who verified that adults of *S. frugiperda* presented significant reduction of 60% of laid eggs and 46.8% of viability after ingestion of honey + tebufenozide (a growth regulator from diacil-hidrazine group), but without decrease in longevity of adults. The authors observed that the growth regulator lufenuron did not affect fecundity or longevity when ingested by females of *S. frugiperda*, but reduced the average viability of eggs in 93%.

Table 5 - Percentage of female *Dorus luteipes* (Dermaptera: Forficulidae) posture and egg viability (%) from couples who consumed eggs of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) treated with insecticides and provided at time intervals to the predator

Treatment	Females with posture[1](%)			Egg viability (%)[1]		
	1 h	24 h	48 h	1 h	24 h	48 h
Water	54.16±10.34 Aa	41.7±13.7 Aa	41.7±13.7 Aa	96.16±4.5 Aa	100±0.0 Aa	100±0.0 Aa
Triflumurom	25.0±0.77 Ba	20.8±4.1 Ba	20.8±4.1 Ba	0.0±0.0 Bb	7.62±5.38 Ba	0.0±0.0 Bb
Thiamethoxan/λ-cyhalothrin	0.0±0.0 Ca	0.0±0.0 Ca	0.0±0.0 Ca	-	-	-
Teflubenzuron/α-cypermethrin	0.0±0.0 Ca	0.0±0.0 Ca	0.0±0.0 Ca	-	-	-
Chlorfenapyr	25.0±0.77 Ba	25.0±6.4 Ba	33.3±4.11 Aa	0.0±0.0 Ba	0.0±0.0 Ca	0.0±0.0 Ba
Etofenproxi	29.0±10.8 Ba	37.5±5.7 Aa	25.0±3.86 Ba	0.0±0.0 Ba	0.0±0.0 Ca	0.0±0.0 Ba
Spinosad	0.0±0.0Ca	0.0±0.0 Ca	0.0±0.0 Ca	-	-	-

[1]Mean followed by the same letter, in uppercase or lowercase column lines for each insecticide, do not differ by Scott-Knott test (SCOTT; KNOTT, 1974) at 5% significance

CONCLUSIONS

1. Triflumuron is harmless; chlorfenapyr and etofenprox are slightly harmful; teflubenzuron/α-cypermethrin and spinosad are moderately harmful; thiamethoxan/λ-cyhalothrin is harmful when directly applied on adults of *D. luteipes*;

2. Triflumuron is slightly harmful; thiamethoxan/λ-cyhalothrin, teflubenzuron/α-cypermethrin, etofenprox and spinosad are harmless when applied to surfaces on which adults of the predator are kept;

3. The insecticides thiamethoxan/λ-cyhalothrin and teflubenzuron/α-cypermethrin are slightly harmful to adults that ingest contaminated eggs, being the other compounds harmless;

4. Due to the low toxicity presented by triflumuron this compound can be used in integrated pest management programs in areas where the predator *D. luteipes* is present. The other products should be evaluated in the greenhouse and field for evidencing their toxicity.

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