

Toxicity and residual effects of toxic baits with spinosyns on the South American fruit fly

Inana Xavier Schutze⁽¹⁾, Cléber Antonio Baronio⁽¹⁾, Morgana Mattiello Baldin⁽¹⁾,
Alci Enimar Loek⁽²⁾ and Marcos Botton⁽¹⁾

⁽¹⁾Embrapa Uva e Vinho, Rua Livramento, nº 515, CEP 95701-008 Bento Gonçalves, RS, Brazil. E-mail: i_schutze@hotmail.com, cleber.baronio@hotmail.com, morgana.baldin13@gmail.com, marcos.botton@embrapa.br ⁽²⁾Universidade Federal de Pelotas, Campus Universitário, Caixa Postal 354, CEP 96010-970 Pelotas, RS, Brazil. E-mail: alcienimar@yahoo.com.br

Abstract – The objective of this work was to assess the lethal concentration and lethal time (LC and LT) of spinosad and spinetoram, combined with different food lures, and their residual effects on South American fruit fly (*Anastrepha fraterculus*). The toxic baits were offered in eight concentrations (2, 6, 14, 35, 84, 204, 495, and 1,200 mg L⁻¹), combined with the following food lures: 7% sugarcane molasses, 3% Biofruit, 1.5% CeraTrap, 1.25% Flyral, 3% Samaritá Bait, and 3% Samaritá Tradicional; diluted food lures in water were used as controls. The residual effect of the formulations at 96 mg L⁻¹ concentration were evaluated for 21 days and were compared with that of the commercial bait Success 0.02 CB. Both insecticides were toxic to adults of *A. fraterculus*, and mortality varied with the food lure used. The LC₅₀ and LT₅₀ ranged from 15.19 to 318.86 mg L⁻¹ and from 11.43 to 85.93 hours, respectively. Spinosad was 2 to 36 times as toxic as spinetoram when combined with different hydrolyzed proteins. Toxic baits formulated with spinosad and spinetoram (96 mg L⁻¹) caused mortality equivalent to the one by Success 0.02 CB (90.2%), when assessed on the day of application. Toxic baits formulated with 3% Biofruit + spinosad and 3% Samaritá Bait + spinetoram are effective for managing *A. fraterculus* and provide up to seven days of residual effect in the absence of rain; however, only Success 0.02 CB caused more than 80% mortality for up to 21 days.

Index terms: *Anastrepha fraterculus*, hydrolyzed protein, spinetoram, spinosad, sugarcane molasses.

Toxicidade e efeitos residuais de iscas tóxicas à base de espinosinas sobre a mosca-das-frutas sul-americana

Resumo – O objetivo deste trabalho foi determinar a concentração e o tempo letal (CL e TL) de espinosade e espinetoram, associados a diferentes atrativos alimentares, e seus efeitos residuais sobre a mosca-das-frutas sul-americana (*Anastrepha fraterculus*). As iscas tóxicas foram ofertadas em oito concentrações (2, 6, 14, 35, 84, 204, 495 e 1.200 mg L⁻¹), associadas aos atrativos alimentares: 7% de melão de cana-de-açúcar, 3% de Biofruit, 1,5% de CeraTrap, 1,25% de Flyral, 3% de isca Samaritá e 3% de Samaritá Tradicional; os atrativos alimentares diluídos em água foram utilizados como testemunha. O efeito residual das formulações à concentração de 96 mg L⁻¹ foi avaliado por 21 dias e comparado ao da isca comercial Success 0.02 CB. Ambos os inseticidas foram tóxicos aos adultos de *A. fraterculus*, e a mortalidade variou de acordo com o atrativo empregado. A CL₅₀ e o TL₅₀ variaram de 15,19 a 318,86 mg L⁻¹ e de 11,43 a 85,93 horas, respectivamente. O espinosade foi de 2 a 36 vezes mais tóxico que o espinetoram quando associado às diferentes proteínas hidrolisadas. As iscas tóxicas formuladas com espinosade e espinetoram (96 mg L⁻¹) causaram mortalidade equivalente àquela causada por Success 0.02 CB (90,2%) quando avaliadas no dia da aplicação. As iscas tóxicas formuladas com Biofruit a 3% + espinosade e isca Samaritá a 3% + espinetoram são eficazes para o manejo de *A. fraterculus* e apresentam efeito residual de até sete dias, na ausência de chuva; porém, somente Success 0.02 CB causou mais de 80% de mortalidade por até 21 dias.

Termos para indexação: *Anastrepha fraterculus*, proteína hidrolisada, espinetoram, espinosade, melão de cana-de-açúcar.

Introduction

The South American fruit fly *Anastrepha fraterculus* (Weidemann, 1830) (Diptera: Tephritidae) is the main fruit pest in Southern Brazil (Nava &

Botton, 2010). Direct damage is caused by females penetrating the fruit with the ovipositor, and by the larvae developing inside the fruit (Botton et al., 2016). Indirect damage is caused by pathogens entering at the injury site, which accelerates fruit rot

(Machota Júnior et al., 2013). Adults and also larvae of *A. fraterculus* have been successfully controlled with organophosphate insecticides sprayed on the plants (Harter et al., 2015). However, most systemic organophosphate insecticides have been withdrawn from the market, mainly because of serious concerns about side effects on human health and the environment (Nava & Botton, 2010; Botton et al., 2016). This scenario makes it necessary to develop new strategies for fruit fly control.

The use of toxic baits, consisting of a food lure combined with a lethal agent, is one of the main alternatives to suppress adult fruit flies as a substitute for organophosphate applications in orchards (Borges et al., 2015). The toxic bait can be formulated by the grower by mixing a food lure with a lethal agent (insecticide), or with ready-to-use formulations (as Success 0.02 CB) (Borges et al., 2015; Harter et al., 2015). However, for the toxic baits to be effective, several aspects should be taken into consideration, especially the choice of food lure as attractant (Raga et al., 2006). Sugarcane molasses is the main food lure used to formulate toxic baits in Southern Brazil (Harter et al., 2010), as sugars act as phagostimulants, increasing the amount of bait ingested (Nestel et al., 2004). Although sugarcane molasses is effective and low-cost, it is used in a high concentration (7%), making it necessary to store large volumes in the farm; besides, as a residue of the sugarcane industry, molasses is not standardized, and it is often contaminated with substances that negatively affect the efficacy of the compound (Harter et al., 2015).

Hydrolyzed proteins are another food lure to be employed in toxic baits for fruit flies. The use of toxic baits is based on the principle that newly emerged females require a protein source to complete the development of ovaries and to begin mating (Christenson & Foote, 1960; Bateman, 1972). Several commercial formulations of hydrolyzed proteins of both plant and animal origin are available in the market (Botton et al., 2016).

Although organophosphates are still the main insecticides employed as lethal agents in fruit fly toxic baits (Harter et al., 2010; Borges et al., 2015), spinosyns have received more attention because of their lower toxicity to humans and the environment. Spinosyns are also more selective for beneficial insects, and have shorter preharvest intervals (Galm & Sparks, 2015).

Spinosad is the lethal agent of the commercial bait Success 0.02 CB. Spinetoram is another spinosyn derived from spinosad and consists of 3'-O-ethyl-5.6-dihydro-spinosyn J (main component) and 3'-O-ethyl-spinosyn L (secondary component) (Galm & Sparks, 2015). Both spinosyns have been reported as effective in controlling species of Tephritidae (Yee et al., 2007; Stark et al., 2013).

Although a commercial bait formulation with spinosad (Success 0.02 CB) is available, growers often prefer to mix their own toxic baits by combining different attractants with spinosyns in the farms.

The objective of this work was to assess the lethal concentration and lethal time (LC and LT) of spinosad and spinetoram, combined with different food lures, and their residual effects on South American fruit fly.

Materials and Methods

The experiments were performed in the Laboratory of Entomology of Embrapa Uva e Vinho (at 25±2°C, 75±15% relative humidity, and 12-hour photophase), in Bento Gonçalves, RS, Brazil. Adults of *A. fraterculus* were obtained from the fourth generation of the laboratory colony and maintained following Machota Júnior et al. (2010), using mango (*Mangifera indica* L. 'Tommy Atkins' as the substrate for oviposition and larval development, rather than papaya (*Carica papaya* L.).

Six food lures were assessed: the hydrolyzed corn protein Biofruit at 3% (Biocontrole Método de Controle de Pragas Ltda., Indaiatuba, SP, Brazil); the enzymatic hydrolyzed animal protein CeraTrap at 1.5% (BioIbérica S.A., Barcelona, Spain); the enzymatic hydrolyzed protein of animal origin Flyral at 1.25% (BioIbérica S.A., Barcelona, Spain); the hydrolyzed corn protein Samaritá Bait at 3% (Samaritá Indústria e Comércio Ltda., Artur Nogueira, SP, Brazil); the vegetable protein, with reducing sugars and preservatives Samaritá Tradicional at 3% (Samaritá Indústria e Comércio Ltda., Artur Nogueira, SP, Brazil); and sugarcane molasses at 7%. The concentrations of food lures were based on the manufacturer recommendations and on practical experience.

Toxic baits were prepared by mixing food lures with either the insecticide Tracer 480 SC (spinosad 480 g L⁻¹) or Delegate 250 WG (spinetoram 250 g L⁻¹)

(Dow AgroSciences Industrial Ltda., São Paulo, SP, Brazil). The commercial bait formulation Success 0.02 CB (0.24 g L^{-1}) (Dow AgroSciences Industrial Ltda., São Paulo, SP, Brazil), diluted with water at a ratio of 1 part of the commercial product to 1.5 part of water, as recommended by the manufacturer, for a final concentration of 96 mg L^{-1} was used as a standard reference.

In order to determine the lethal concentration (LC_{50} and LC_{80}) of the baits, the insecticides Tracer 480 SC (spinosad 480 g L^{-1}) and Delegate 250 WG (spinetoram 250 g L^{-1}) were diluted at logarithmically sequenced concentrations (2, 6, 14, 35, 84, 204, 495, and $1,200 \text{ mg L}^{-1}$) defined in previous experiments that provided mortality values from 10 to 90%; in all experiments, the diluted food lures in water were used as controls. Later, 10 to 14-day-old adults of *A. fraterculus* from the laboratory colony were starved for 12 hours. After that time, 10 adults (five males and five females) were transferred to cages made of transparent plastic cups (300 mL) inverted on a paper towel (12 cm diameter). For the ventilation and gas exchange, the bottom of the cups was removed and covered with voile. The toxic baits were then offered for four hours on plastic plates ($20 \times 20 \text{ mm}$) containing a drop of $40 \mu\text{L}$ per cage. After that, the toxic baits were removed, and the flies fed a 10% honey solution offered via capillarity on moistened cotton wools. The mortality was assessed 96 hours after the treatment (HAT), considering as dead insects those which were unresponsive to the touch of a fine brush. The experimental design was completely randomized, with 12 replicates per treatment.

To determine the lethal time (LT_{50} and LT_{95}) of the bait formulations, the insecticides Tracer 480 SC or Delegate 250 WG were diluted at 96 mg L^{-1} of the active ingredient, using as a standard the ready-to-use bait formulation (Success 0.02 CB, at the 96 mg L^{-1} concentration), following the methodology above described. Adult mortality was assessed 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 36, 48, 60, 72, 84, and 96 HAT.

To evaluate the residual effect of the baits, the same LT experimental treatments were applied on leaves of citrus plants 'Valencia' grown in 5 L buckets, which contained two parts of soil and one part of vermiculite and were maintained in a greenhouse. The treatments were applied with a unicanal micropipette (Pipetman

U76928A), with one drop ($40 \mu\text{L}$) of toxic bait per leaf. After 0, 7, 14, and 21 days after application of the treatments, the leaves from each treatment were removed and taken to the laboratory by placing them in plastic cages (300 mL), using the same methodology as the experiment of lethal concentration. Insect mortality was evaluated 96 hours after the bait was provided. The experimental design was completely randomized, with 10 replicates per treatment, with five couples per replicate. Mortality was calculated with the formula by Abbott (1925).

To determine the lethal concentrations (LC_{50} and LC_{80}) and lethal times (LT_{50} and LT_{95}), and their respective confidence intervals (95% CI), concentration-mortality data were subjected to Probit analysis using the program PC-Polo (Leora Software, Berkeley, CA, USA). The hypothesis that the LC and LT values were equal was evaluated with an F-test. When the hypothesis was rejected, paired comparisons were made, and significance was accepted when there was no overlap of confidence intervals (Robertson et al., 2007).

To evaluate the residual effect and the interaction among treatments (food lure, insecticide, and exposure time of adult *A. fraterculus* to toxic baits), data were subjected to two-way analysis of variance using Proc GLM in SAS 9.1, with the food lure and insecticide variables as fixed factors. The interactions between the variables were determined by least square values (PDIF option in Proc GLM), with adjustment by the Tukey's test, at 5% probability (SAS Institute, Cary, NC, USA). Subsequently, the data for survival of adult *A. fraterculus* underwent exploratory analysis to check the normality of the residuals, and normal data were transformed by the equation [square root ($x + 0.5$)]. Subsequently, the data were subjected to analysis of variance, and means were compared by the Tukey's test at 5% probability, using the SPSS program 24.0 (SPSS Inc., Chicago, IL, USA).

Results and Discussion

All toxic bait formulations were toxic to adults of *A. fraterculus* (Table 1). Toxic baits based on hydrolyzed proteins formulated with spinosad showed higher biological activity on adults of *A. fraterculus*, with lower LC_{50} and LC_{80} than with the spinetoram formulations (Table 1). In general, spinetoram was also

toxic to adults of *A. fraterculus*; however, when the insecticides were combined with hydrolyzed proteins, a higher dose (2 to 36 times) was required, in order to obtain the same mortality of spinosad. This difference for mortality was not observed when the insecticides were combined with sugarcane molasses, which indicates a variation in the toxicity of compounds combined with the offered food lure. Hydrolyzed proteins resulted in lower LC₅₀ values when combined with spinosad, while the food lure with a higher concentration of carbohydrates resulted in lower-LC₅₀ values when combined with spinetoram, which may be related to phagostimulation caused by sugarcane molasses.

In general, food lures used for the management of fruit flies are based on a combination of hydrolyzed protein (attractant) with sugar (phagostimulant), which stimulates the insects to search for and ingest the bait (Nestel et al., 2004; Bortoli et al., 2016). Baits that contained this mixture at the same concentration resulted in a higher mortality and lower LT₉₅ than with Success 0.02 CB which, in addition to the lethal agent spinosad, contains a mixture of sugar, protein, ammonium acetate, and other ingredients (Yee & Chapman, 2005), as well as hydrolyzed proteins of vegetable origin. Although sugarcane molasses acts as a phagostimulant due to the high concentration of sucrose (Feltrin et al., 2000; Yee & Alston, 2016), it may not trigger the same search response.

Several studies have shown the biological activity of spinosad on *A. fraterculus* and suggested it as a potential replacement for malathion in toxic baits (Raga & Sato, 2005; Harter et al., 2015). In the present study, for a mortality rate of 80%, a minimum concentration of 167.41 mg L⁻¹ of spinosad was required. This concentration is twice as high as the concentration found in the commercial bait Success 0.02 CB, when the insecticide was combined with the food lure Samaritá Tradicional. Raga & Sato (2005) found 106 min of LT₅₀ for *A. fraterculus*, at 80 mg L⁻¹ spinosad, which is far below the more than 11 hours obtained in the present study. The difference in the LT may be related to the available volume (1 mL) and offering period (24 hours) of the bait, which in the study by Raga & Sato (2005) were higher than those used here (40 µ L volume and 4 hours of offering period).

The lethal times (LT) of adult *A. fraterculus* exposed to toxic bait formulations containing spinosad or spinetoram, at a concentration of 96 mg L⁻¹, differed significantly (Table 2). The lowest LT₅₀ and LT₉₅, in hours, were observed for the formulations Samaritá Tradicional + spinetoram, and Biofruit + spinosad; and the highest ones with CeraTrap + spinetoram (Table 2). These differences may be related to the speed of ingestion and subsequent assimilation of different proteins and spinosyns, which act primarily by ingestion (Vontas et al., 2011; Borges et al., 2015). Based on the overlap of confidence intervals of the LT₉₅ values estimated for

Table 1. Lethal medium concentrations (LC₅₀ and LC₈₀, in mg L⁻¹) of toxic-bait formulations for the control of *Anastrepha fraterculus*.

Food lure	Insecticide	Slope±standard error	LC ₅₀ (CI 95%)	LC ₈₀ (CI 95%)	χ ²
Sugarcane molasses 7%	Spinosad	0.881±0.065	97.69 (73.92–129.14)	882.14 (602.33–1418.99)	5.47
	Spinetoram	0.710±0.055	47.10 (34.40–63.71)	722.66 (469.18–1250.47)	5.66
Biofruit 3%	Spinosad	0.792±0.067	15.19 (9.34–22.73)	175.64 (120.56–270.74)	5.49
	Spinetoram	0.965±0.082	84.10 (59.02–115.97)	626.90 (434.97–981.29)	5.66
Flyral 1.25%	Spinosad	0.892±0.065	49.69 (35.08–68.80)	436.50 (265.10–860.30)	9.09
	Spinetoram	0.495±0.054	318.86 (193.23–606.50)	15,953.00 (5,644.50–76,042.00)	4.86
CeraTrap 1.5%	Spinosad	1.035±0.065	72.11 (51.21–100.60)	469.26 (311.01–799.48)	8.50
	Spinetoram	0.483±0.055	154.23 (67.00–416.67)	8,505.80 (2,098.70–131,060.00)	9.99
Samaritá Tradicional 3%	Spinosad	1.080±0.067	27.84 (18.84–39.67)	167.41 (112.61–275.99)	9.73
	Spinetoram	0.970±0.063	67.73 (49.51–92.21)	499.56 (336.38–825.57)	6.49
Samaritá Bait 3%	Spinosad	1.131±0.084	50.00 (37.43–64.52)	277.22 (213.53–374.63)	4.93
	Spinetoram	1.031±0.065	96.19 (69.24–134.32)	629.70 (410.48–1104.31)	8.34

⁽¹⁾Chi-square value at 5% probability, with six degrees of freedom.

all toxic bait formulations; only the combination of Biofruit + spinosad ($LT_{95} = 139.28$) was equivalent to the ready-to-use formulation Success 0.02 CB ($LT_{95} = 95.99$) (Table 2). The other combinations required more time to reach 95% mortality. In general, a higher biological activity and a shorter period of time to kill the flies were obtained with the toxic baits formulated with spinosad than with spinetoram, except for the Samaritá Bait. Although both insecticides are in the same chemical group, this difference in the initial toxicity (spinosad > spinetoram) was also observed for *Rhagoletis pomonella* (Walsh) (Yee et al., 2007). This difference may be related to different metabolic processing of spinosad and spinetoram by members of Tephritidae, since a higher biological activity was obtained with spinetoram than spinosad for insects of other families (Galm & Sparks, 2015).

As to the residual effect at the days after the application of the treatment (DAAT), Flyral + spinetoram 96 mg L⁻¹ provided the lowest mortality of adult *A. fraterculus* (61%) at 0 DAAT, differing significantly ($F_{20, 189} = 33.38$; $p < 0.0001$) from the commercial bait formulation Success 0.02 CB (Table 3), while the other formulations caused mortality rates from 72.6 (Flyral + spinosad 96 mg L⁻¹) to 89.1% (Samaritá Bait + spinosad 96 mg L⁻¹), which is equivalent to Success 0.02 CB (90.2% mortality) (Table 3). However, at 7 DAAT, only Biofruit + spinosad

(67.9%) and Samaritá bait + spinetoram (75.5%) performed similarly to Success 0.02 CB (92.3%).

At 14 and 21 DAAT, all toxic baits formulated with food lures using spinosad or spinetoram at a concentration of 96 mg L⁻¹ showed a significant decreasing mortality of adult *A. fraterculus* over time. In contrast, the commercial formulation Success 0.02 CB maintained a mortality rate above 90% until 21 DAAT (90.2%), indicating the presence of components in the formulation that improve the stability of the active ingredient. Within this time frame, other toxic baits caused low mortality, which ranged from 17.6% (Flyral + spinosad 96 mg L⁻¹) to 48.8% (sugarcane molasses + spinosad 96 mg L⁻¹) (Table 3). Similar decreases in the residual activity of spinosad and spinetoram at 3 and 7 DAAT were reported for *R. pomonella* (Yee et al., 2007) and *A. fraterculus* (Borges et al., 2015; Harter et al., 2015). The short spinetoram activity period can be related to the rapid degradation of the insecticide in the presence of light (Gazit et al., 2013) or absorption by the plant, as with the spinosad, making them unavailable to the flies (Yee et al., 2007). In the case of Success 0.02 CB, the formulation contains ingredients that reduce the degradation (Flores et al., 2011), extending the period of effectiveness.

Previous studies have also shown a low residual effect of formulations of spinosad mixed with Biofruit and sugarcane molasses (Harter et al., 2015). In contrast, in the present study, Success 0.02 CB

Table 2. Lethal time in hours (LT_{50} and LT_{95}) of toxic bait formulations for the control of *Anastrepha fraterculus*.

Food lure	Insecticide (96 mg L ⁻¹)	Slope±standard error	LT_{50} (CI 95%)	LT_{95} (CI 95%)	χ^2 ⁽¹⁾
Sugarcane molasses 7%	Spinosad	1.684±0.091	18.79 (16.48–21.29)	177.99 (132.91–261.00)	23.58
	Spinetoram	1.535±0.088	16.95 (14.85–19.18)	199.99 (146.86–300.10)	21.00
Biofruit 3%	Spinosad	1.574±0.099	12.56 (10.42–14.67)	139.28 (102.28–213.05)	24.90
	Spinetoram	1.355±0.085	23.57 (21.19–26.28)	385.79 (277.46–585.91)	1.04
Flyral 1.25%	Spinosad	1.238±0.084	19.73 (17.31–22.40)	420.71 (283.47–709.86)	15.21
	Spinetoram	1.170±0.087	56.25 (47.18–70.12)	1,433.66 (797.09–3,233.36)	16.19
CeraTrap 1.5%	Spinosad	1.234±0.085	31.03 (27.55–35.31)	667.81 (442.21–1140.93)	13.37
	Spinetoram	0.897±0.085	85.93 (67.10–120.30)	5,873.6 (2,460.1–2,0741.0)	5.36
Samaritá Traditional 3%	Spinosad	1.565±0.090	32.21 (28.40–36.98)	362.30 (251.43–588.35)	21.72
	Spinetoram	1.345±0.088	11.43 (9.95–12.90)	190.94 (144.46–272.32)	7.60
Samaritá Bait 3%	Spinosad	1.799±0.093	17.52 (16.06–19.05)	143.76 (118.11–182.23)	7.20
	Spinetoram	1.536±0.088	18.15 (15.78–20.72)	213.81 (153.23–334.11)	23.86
Success 0.02 CB	Spinosad	2.329±0.105	18.88 (17.51–20.33)	95.99 (82.38–115.12)	15.04

⁽¹⁾Chi-square value at 5% probability, with 15 degrees of freedom.

(spinosad), used as a reference for mortality effects on *A. fraterculus*, showed high biological activity on the insects until 21 DAAT. Harter et al. (2015) also recorded a satisfactory mortality (>80%) in adults of *A. fraterculus* until 7 DAAT. These results show that other factors may be affecting the residual effect of the formulations, especially the type of food lure used in the mixture with the insecticide, which may cause variation in the phagostimulation power (Nunes et al., 2013), drop size, and viscosity of the formulation (Mangan et al., 2006; Gazit et al., 2013).

The known toxicity of spinosad to *A. fraterculus* makes this insecticide a viable alternative for the management of pests with toxic baits (Mangan et al., 2006; Nava & Botton, 2010; Borges et al., 2015; Galm & Sparks, 2015; Harter et

al., 2015). The present study showed that spinetoram can also be employed, as it caused more than 80% mortality. *A. fraterculus* proved to be less susceptible to spinetoram when combined with an attractant containing protein ingredients, but had the same residual effect as spinosad at the same concentration. This was found for the formulation with Samaritá Bait that remained effective for 7 days, which is equivalent to the residual effect observed for spinosad combined with Biofruit.

The toxic baits made with spinosyns caused a high mortality in adults of *A. fraterculus*, although the effective concentration of the lethal agent varied depending on the food lure (Tables 1, 2 and 3). Considering as acceptable an 80% mortality rate of adults of *A. fraterculus*, and comparing the

Table 3. Mean number of *Anastrepha fraterculus* alive (N±SE) and percentage of mortality (M%) 96 hours after exposure to residues of toxic baits made with spinosad and spinetoram, on citrus leaves at 0, 7, 14, and 21 days after application of the treatments (DAAT)⁽¹⁾.

Active ingredient (96 mg. L ⁻¹)	0		7		14		21	
	N±SE	M% ⁽²⁾	N±SE	M%	N±SE	M%	N±SE	M%
Sugarcane molasses 7%								
Spinosad	1.7±0.47Eb	82.2	4.5±0.49DEFGab	70.0	2.6±0.40CDa	49.4	4.9±0.57EFa	48.8
Spinetoram	1.8±0.54Ec	81.3	3.0±0.50EFGbc	61.8	4.0±0.42Db	53.8	6.0±0.37BCDEFa	37.3
	9.6±0.28Aa	-	8.9±0.30Aab	-	8.7±0.31Aab	-	9.6±0.19Aa	-
Biofruit 3%								
Spinosad	1.3±0.35Eb	85.2	1.5±0.53FGHa	67.9	4.3±0.49BCDa	40.8	5.9±0.63DEFa	34.8
Spinetoram	1.9±0.48Eb	78.4	4.6±0.43BCDEFa	47.6	4.7±0.49BCDa	47.2	4.6±0.56EFa	35.9
	8.8±0.38Aa	-	8.1±0.25ABCDa	-	8.6±0.35Tab	-	8.8±0.34ABCDa	-
CeraTrap 1.5%								
Spinosad	2.0±0.77Eb	78.1	3.8±0.59BCDEab	54.6	5.9±0.66BCDa	33.5	5.8±0.47ABCDEFa	34.0
Spinetoram	2.1±0.35DEb	76.3	4.6±0.33CDEFa	46.3	4.3±0.42ABCDa	46.2	5.3±0.64Fa	34.5
	9.1±0.33Aa	-	8.7±0.26Aab	-	8.6±0.34ABCa	-	9.4±0.21Aab	-
Flyral 1.25%								
Spinosad	1.9±0.58DEb	72.7	3.6±0.55EFGab	52.2	4.4±0.63ABCDa	32.2	6.6±0.70ABCDEa	17.6
Spinetoram	3.6±0.38CDab	61.0	4.4±0.44DEFa	50.0	4.4±0.62Of	49.2	4.8±0.72EFa	47.3
	8.8±0.37Aa	-	9.3±0.34Aab	-	8.7±0.35Aab	-	9.1±0.37ABCa	-
Samaritá Bait 3%								
Spinosad	1.0±0.32Eb	89.1	3.8±0.86BCDEFa	57.8	5.5±0.78BCDa	41.3	5.9±0.65CDEFa	36.2
Spinetoram	1.7±0.40Ec	81.5	2.3±0.57FGHbc	75.5	4.3±0.74Dab	52.2	6.1±0.54ABCDEFa	25.0
	9.2±0.24Aa	-	9.4±0.39Aa	-	9.0±0.29Aab	-	9.3±0.23Aa	-
Samaritá Traditional 3%								
Spinosad	2.2±0.42DEb	75.9	3.9±0.61BCDEFa	57.1	5.2±0.40BCDa	42.9	5.2±0.44EFb	36.1
Spinetoram	1.2±0.37Ec	86.8	3.0±0.47DEFGb	67.2	4.3±0.62Cdb	47.2	6.2±0.51ABCDEFa	32.0
	9.0±0.35Aa	-	8.1±0.37ABCa	-	9.1±0.37Aa	-	9.1±0.33ABCa	-
Success 0.02 CB								
Spinosad	0.5±0.16Ea	90.2	0.8±0.39Ha	92.3	0.8±0.28Ea	94.2	0.9±0.39Ga	90.2
Water	8.1±0.28ABb	-	9.1±0.24Aab	-	8.6±0.21ABab	-	9.2±0.24Aab	-

⁽¹⁾Means followed by capital letters in the columns, and lowercase in the lines, do not differ by the Tukey's test, at 5% probability. ⁽²⁾Mortality calculated by the formula of Abbott (1925). SE, standard error.

two spinosyns at the same concentrations in the toxic bait Success 0.02 CB, only the commercial formulation provided a satisfactory control until 21 DAAT. The remaining toxic bait formulations were equivalent to commercial formulation only on the day of application, highlighting the formulations Biofruit + spinosad and Samaritá Bait + espinetoram) at 7 DAAT, common period of reapplication of toxic baits in the field (Raga, 2005; Harter et al., 2015). The use of higher concentrations of spinosyns in the bait formulations could cause a mortality increase, since the assessed concentration (96 mg L⁻¹) is less than all LC₈₀ values obtained. Considering the best food lure combinations with the spinosyns, the minimum concentration of spinosad and spinetoram that should be employed would be 167.41 mg L⁻¹ and 499.56 mg L⁻¹, respectively, with the Biofruit and Samaritá Tradicional lures.

The biological activity of the products varies according to the type of food lure used. Spinosad is generally more active than spinetoram at the same concentrations using attractants based on hydrolyzed protein. The use of spinosad or spinetoram in toxic bait formulations allows growers to use these insecticides for the management of adult *A. fraterculus* close to the harvest period, with lower risks of leaving toxic residues on the fruit. Besides its greater biological activity than spinetoram, spinosad is accepted for use on organic crops abroad (OMRI, 2016). However, in Brazil, spinosad is not authorized for employment on most fruits from temperate climates (Agrofit, 2016) and, in these cases, spinetoram can be an alternative to organophosphates as a lethal agent.

Conclusions

1. Spinosad and spinetoram are toxic to adults of the South American fruit fly (*Anastrepha fraterculus*) in bait formulations, but the biological activity of the products varies according to the type of food lure used.

2. Toxic baits formulated with Biofruit at 3% + spinosad and Samaritá Bait at 3% + spinetoram are effective for the management of *A. fraterculus* and provide up to seven days of residual effect.

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