

Effect of Food Attractants and Insecticide Toxicity for the Control of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Adults

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Abstract

An alternative for the population suppression of *Spodoptera frugiperda* is the use of toxic baits. The objective of this study was to evaluate the dietary preference and toxic effect of insecticides associated with the attractiveness of *S. frugiperda* adults as a pest management method. The following attractions were tested: 1) 5% sucrose solution, 2) 10% sugarcane syrup, 3) 10% honey, 4) 5% hydrolyzed protein, 5) Noctovi[®] 43sb, 6) Noctovi[®] OVI PLU 1-3, 7) Noctovi[®] OVI PHE/PAL 50-50 in the study with choice. Attractions: 1) sugarcane syrup 10%, 2) Noctovi[®] 43sb, 3) Noctovi[®] 43sb + sugarcane syrup 10%, 4) Noctovi[®] OVI PLU 1-3 in the study with no chance of choice. For the toxicity study, the food attraction associated with insecticides was used: methomyl 2%, lambda-cyhalothrin 1%, chlorpyrifos 2%, spinosad 1%, chlorantraniliprole 2% and chlorfenapyr 2%. The experimental design was the completely randomized design (CRD) with chance of choice, without chance of choice and toxicity. The following parameters were evaluated: number of insects that fed; time in minutes that remained in the attractive food and mortality. The molasses (10%) and Noctovi[®] 43sb food attractiveness were significantly more efficient in relation to feeding time and the highest number of landings was observed in the Noctovi[®] 43sb treatment, both in females and total adults. Methomyl, lambda-cyhalothrin and spinosad insecticides associated with food attractiveness are promising toxic baits for the management of *S. frugiperda*.

Keywords: attracts and kills, toxic bait, alternative control, integrated pest management

1. Introduction

The monitoring is the fundamental step in the implementation of an Integrated Pest Management (IPM) program. Controlling the pest at the right time and with the right product can lead to money savings, make the target pest control program more efficient, and help preserve beneficial organisms on the farm. There are many methods of monitoring pest insects, one of which is by monitoring adult insects using appropriate traps. Such traps are considered useful tools in IPM if used correctly (Cruz et al., 2010).

The fall armyworm *Spodoptera frugiperda*, (J.E. Smith, 1797) (Lepidoptera: Noctuidae) is the most important pest in maize cultivation, and because it is polyphagous, it uses several commonly occurring hosts in different agroecosystems. Casmuz et al. (2010) reported the occurrence of this species in approximately 186 plant species belonging to 42 different families, in their distribution and occurrence zone.

The losses caused by the pest can cause a reduction in grain yield of up to 60%, the damage resulting from the attack can occur from the emergence phase of the seedlings to the reproductive phase of the crop (Cruz, 2008; Cruz et al., 2013).

The chemical control and the use of genetically modified plants (Bt plants) are the main techniques currently used, however it has shown control failures due to the resistance of insects to insecticides and Bt proteins (Carvalho et al., 2013; Goulart et al., 2015). Thus, the use of different management strategies for fall armyworm control should be employed, aiming at reducing caterpillar infestations and consequently crop damage.

Food attractants and semi-chemicals have been investigated as alternatives for the behavioral management of different pests in plants. The chemical substances that indicate the presence of nutrient in them are in many cases, secondary compounds of plants that stimulate chemoreceptor cells, located in the taste cells of the tarsus,

antennas and parts of the oral apparatus of insects, and that induce, among other actions, feeding and oviposition (Nation, 2002).

The use of semi-chemicals and food attractants in pest control actions is in accordance with the model recommended for future agriculture. It is a technique that has high specificity, not presenting any deleterious effect to the species that are not subject to control and no chemical residue is deposited in the environment or in the food produced. Among the identified semi-chemicals are sexual and aggregation pheromones, attractive compounds used in traps, floral compounds and glandular compounds, among others (Zarbin et al., 2009).

Toxic bait with food stimulants have been used for the identification and distribution of insect species, certification of a region or country as to the absence of a certain pest species (free area), and in pest species eradication and integrated management programs (Nascimento et al., 2000). Several attractions such as brown sugar, sucrose, corn hydrolyzed protein, fruit juices and wine vinegar are used in traps for insects monitoring and, when added to insecticides, they are recommended for the pests control, such as fruit flies (Nascimento et al., 2000; Gravena & Benvenga, 2003; Benvenga et al., 2007). Synthetic pheromones, such as Noctovi[®], have recently been launched and have proven to be important allies for sampling and pest control (Silva et al., 2016).

Considering the possibility of developing methods to control adults of *S. frugiperda*, this study aimed to evaluate the effect of food attractants and their association with insecticides on adults of this pest under laboratory conditions.

2. Materials and Methods

2.1 Fall Armyworm Adult Preparation

The experiments were conducted at the Insect Sampling and Monitoring Laboratory of the Federal University of Grande Dourados in the city of Dourados, Mato Grosso do Sul, Brazil. The pupae of *S. frugiperda* were acquired from the Pragmas.com company specialized in the creation and marketing of insect pests, based in the city of Piracicaba, state of São Paulo, Brazil.

The pupae were kept in controlled conditions of temperature (26.5 ± 2 °C), relative humidity ($75 \pm 1.5\%$) and photophase (12 hours).

Sexing occurred according to the methodology described by Zenker et al. (2007), conditioning adults in cages made of polyethylene tube with its ends closed with voil. The males and females were kept separated, being released as couples for the tests with chance of choice and without chance of choice, at six hours after the composition of the couples, to evaluate the toxicity of food attractions associated with insecticides.

To perform the bioassays, another room (3 × 5 meters) was also used on the premises of the Laboratory of Sampling and Monitoring of Insects, however it had large doors and windows, and simulating natural conditions of the environment without interference as to light, temperature and relative humidity to simulate the real field conditions. The insects were transferred 30 minutes before for previous adaptation and then released.

The release occurred at dusk near sunset and the evaluations occurred in the sequence of the release and at dawn, near and during sunrise. The climatic conditions during the tests with chance, without chance of choice and toxicity were: temperature 27.3 ± 1.89 °C; 28.2 ± 1.01 °C; 28.9 ± 1 °C and relative humidity $88.8 \pm 4.3\%$, $83.7 \pm 5.2\%$ and $79.5 \pm 9.0\%$, respectively.

The bioassays with and without change of choice were composed of 6 repetitions for each treatment, and each repetition was released 5 couples of *S. frugiperda* with 48 to 72 hours of age not fed for a period of 24 hours, except for the toxicity test, where each couple was one repetition and 8 repetitions were used.

2.2 Choice Test

For the first food attractants study with a chance to choose, the experimental design was the completely randomized design (CRD), with 7 treatments and 6 repetitions. The treatments corresponded to the following attractions: 1) 5% sucrose solution, 2) 10% sugarcane syrup, 3) 10% honey, 4) 5% hydrolyzed protein, 5) Noctovi[®] 43sb, 6) Noctovi[®] OVI PLU 1-3, 7) Noctovi[®] OVI PHE/PAL 50-50. The treatments were arranged in a circular arena covered with voil, one meter high by one-meter radius (3.15 meters circumference), and the treatments were placed 45 cm apart. For the negative control was used a treatment with distilled water.

In the second food attractants study with no chance of choice, the experimental design used was in CRD, with 4 treatments that proved promising by previous results of the first study [Attractions: 1) sugarcane syrup 10%, 2) Noctovi[®] 43sb, 3) Noctovi[®] 43sb + sugarcane syrup 10%, 4) Noctovi[®] OVI PLU 1-3]. The treatments were arranged in a circular arena covered with voil, one meter high by one-meter radius (3.15 meters circumference), with each feeding point (treatment) at 78 cm distance from each other with six repetitions performed.

The sampling point was composed of 3 cm³ cotton pads containing 2ml of the solution, fixed with a wooden preacher in the upper part of the arena and visual evaluation, counting the number of male and female landings and the feeding time.

The food attractants for the tests were purchased from the manufacturers and/or authorized distributors obeying the recommendations for storage and use.

2.3 Toxicity Test

For the toxicity study we used the food attraction Noctovi[®] 43sb associated with insecticides of chemical groups and active ingredients: (Carbamate: methomyl—2%), (Pyrethroid: lambda-cyhalothrin—1%), (Organophosphate: chlorpyrifos—2%), (Spinosine: spinosad—1%), (Diamide: chlorantraniliprole—2%) and (Pyrazole analogue: chlorfenapyr—2%), respectively. Eight repetitions were performed, containing a couple aged 24 to 48 hours of life without food. The release occurred at dusk and the evaluations followed in the first 6 h, 12 h, 24 h, 36 h, 48 h and 96 h. Each repetition was composed of a 500-mL plastic cup (with perforated lid), the food attraction associated or not with insecticide was fixed in the upper part of the cup (lid), in a 3 cm³ cotton ball containing 2 mL of solution each.

The active ingredients used came from commercial insecticides available in the Brazilian market duly registered for control *S. frugiperda*.

2.4 Statistical Analysis

The visual evaluations were carried out according to the methodology described by France et al. (2009), separating the insects into males, females and total adults (males + females). The following parameters were evaluated: number of landings, time in minutes that remained in the attractive food and mortality due to contact with toxic baits.

The data obtained in the experiments performed, when they did not meet the normality criteria, were transformed into $\sqrt{x + 0.5}$ to meet the assumptions of ANOVA. Then, the averages obtained in the different treatments by the Tukey's test were compared, at a 5% probability level. The mortality data (%) of the treatments and the control were used to calculate the efficiency of the insecticides using the Abbott method, $Ma = (Mt - Mc)/(100 - Mc) \times 100$, where Ma = mortality corrected for the control treatment; Mt = mortality observed in the treatment with the insecticide and Mc = mortality observed in the control treatment (Abbott, 1925).

3. Results

Negative treatment using only distilled water was excluded from the bioassay because it did not present any attractive effect for moths.

The number of landings observed for males, females and total adults (males + females) of fall armyworm was similar for all food attractants tested: sucrose, honeydew, honey, hydrolyzed protein, Noctovi[®] 43sb, Noctovi[®] OVI PLU 1-3 and Noctovi[®] OVI PHE/PAL. However, for the feeding time (hours) females (32.10±7.96; 29.68±11.16) and total adults (43.49±11.26; 41.68±8.46) the treatments with honeydew and Noctovi[®] 43sb differed significantly from the others except Noctovi[®] OVI PLU 1-3, respectively (Table 1).

The attractive honeydew-based Noctovi[®] 43sb, Noctovi[®] 43sb + honeydew and Noctovi[®] OVI PLU 1-3, subjected to the no-choice test, resembled each other in terms of the number of landings for males and feeding time for both males, females and adults. There was a higher number of landings for females and adults exposed to the food attraction Noctovi[®] 43sb (Table 2).

Table 1. Effect of different food attractants with choice in the behavior of landings (mean \pm standard error) and feeding time (mean \pm standard error) of males, females and adults (males + females) of *Spodoptera frugiperda* under controlled laboratory conditions. UFGD, Dourados, Mato Grosso do Sul, Brazil, 2019

Treatment	Landing ⁽¹⁾	Time (minutes) ⁽¹⁾
<i>Males</i>		
Sucrose (5%)	0.50 \pm 0.22 A	6.95 \pm 3.29 A
Honeydew (10%)	1.00 \pm 0.37 A	12.06 \pm 5.46 A
Honey (10%)	1.00 \pm 0.26 A	7.27 \pm 4.53 A
Hydrolyzed protein (5%)	0.50 \pm 0.22 A	0.05 \pm 0.04 A
Noctovi [®] 43sb	0.67 \pm 0.33 A	12.00 \pm 4.55 A
Noctovi [®] OVI PLU 1-3	0.67 \pm 0.33 A	4.22 \pm 3.07 A
Noctovi [®] OVI PHE/PAL 50-50	0.33 \pm 0.21 A	7.44 \pm 4.72 A
C.V. % ⁽²⁾	31.51	83.26
<i>Females</i>		
Sucrose (5%)	0.33 \pm 0.21 A	3.16 \pm 1.84 A
Honeydew (10%)	1.33 \pm 0.21 A	32.10 \pm 7.96 B
Honey (10%)	0.33 \pm 0.21 A	3.93 \pm 2.69 A
Hydrolyzed protein (5%)	0.83 \pm 0.31 A	0.83 \pm 0.55 A
Noctovi [®] 43sb	1.33 \pm 0.21 A	29.68 \pm 11.16 B
Noctovi [®] OVI PLU 1-3	1.00 \pm 0.33 A	21.35 \pm 5.76 AB
Noctovi [®] OVI PHE/PAL 50-50	0.67 \pm 0.21 A	2.29 \pm 1.34 A
C.V. % ⁽²⁾	25.30	56.31
<i>Adults (males + females)</i>		
Sucrose (5%)	0.83 \pm 0.39 A	10.12 \pm 3.43 A
Honeydew (10%)	2.33 \pm 0.51 A	43.49 \pm 11.26 B
Honey (10%)	1.33 \pm 0.21 A	11.20 \pm 4.04 A
Hydrolyzed protein (5%)	1.33 \pm 0.42 A	0.94 \pm 0.53 A
Noctovi [®] 43sb	2.00 \pm 0.26 A	41.68 \pm 8.46 B
Noctovi [®] OVI PLU 1-3	1.67 \pm 0.61 A	25.56 \pm 6.04 AB
Noctovi [®] OVI PHE/PAL 50-50	1.00 \pm 0.26 A	9.74 \pm 4.15 A
C.V. % ⁽²⁾	24.41	42.27

Note. ⁽¹⁾ Original data with averages followed by the same letter in the columns do not differ from each other by Tukey's test, at 5% probability. ⁽²⁾ C.V. % of data transformed into $\sqrt{x + 0.5}$.

The attractive honeydew-based Noctovi[®] 43sb, Noctovi[®] 43sb + honeydew and Noctovi[®] OVI PLU 1-3, subjected to the no-choice test, resembled each other in terms of the number of landings for males and feeding time for both males, females and adults. There was a higher number of landings for females and adults exposed to the food attraction Noctovi[®] 43sb (Table 2).

No change in adult response to attractiveness was reported, but the presence of insecticides significantly affected the survival of females, males and adults of *S. frugiperda* over time (Figure 1). The percentage of mortality varied over time among the insecticides tested, differentiating them in terms of adult control potential (Table 3 and Figure 1).

Mortality of fall armyworm, caused by insecticides, increased directly within the evaluation periods for males, females and adults (Table 3). Methomyl caused mortality of 50% and 41.7 after one hour of observation for males and total adults. After two hours, the best results were obtained with methomyl and lambda-cyflotriner, 83.3%, 83.3%, 75% and 58.2%, respectively.

Table 2. Effect of different food attractants without chance of choice in the behavior of landings (mean \pm standard error) and feeding time (mean \pm standard error) of males, females and adults (males + females) of *S. frugiperda* under controlled laboratory conditions. UFGD, Dourados, Mato Grosso do Sul, Brazil, 2019

Treatment	Landing ⁽¹⁾	Time (minutes) ⁽¹⁾
<i>Males</i>		
Honeydew (10%)	0.67 \pm 0.33 A	27.57 \pm 10.87 A
Noctovi [®] 43sb	1.33 \pm 0.41 A	32.27 \pm 9.70 A
Noctovi [®] 43sb + Honeydew (10%)	0.50 \pm 0.27 A	20.55 \pm 24.10 A
Noctovi [®] OVI PLU 1-3	1.33 \pm 0.41 A	42.66 \pm 12.48 A
C.V. % ⁽²⁾	28.19	54.82
<i>Females</i>		
Honeydew (10%)	0.50 \pm 0.34 A	6.83 \pm 4.67 A
Noctovi [®] 43sb	1.67 \pm 0.49 B	40.07 \pm 10.10 A
Noctovi [®] 43sb + Honeydew (10%)	1.17 \pm 0.32 AB	35.34 \pm 12.84 A
Noctovi [®] OVI PLU 1-3	1.00 \pm 0.26 AB	33.80 \pm 11.95 A
C.V. % ⁽²⁾	19.91	53.43
<i>Adults (males + females)</i>		
Honeydew (10%)	1.17 \pm 0.60 A	34.40 \pm 13.18 A
Noctovi [®] 43sb	3.00 \pm 0.73 B	72.33 \pm 13.57 A
Noctovi [®] 43sb + Honeydew (10%)	1.67 \pm 0.42 AB	55.89 \pm 22.02 A
Noctovi [®] OVI PLU 1-3	2.33 \pm 0.49 AB	76.47 \pm 17.21 A
C.V. % ⁽²⁾	22.69	36.93

Note. ⁽¹⁾ Original data with averages followed by the same letter in the columns do not differ from each other by Tukey's test, at 5% probability. ⁽²⁾ C.V. % of data transformed into $\sqrt{x + 0.5}$.

In the evaluation after four hours the toxic lures based on methomyl, lambda-cyhalothrin and spinosad insecticides differed significantly from the others, proving the deleterious effect for males and total adults in the order of 83.3%, 100%, 66.7%, 91.7%, 100%, 83.3%, respectively. For females mortality was 100%.

The 12 hours of observation, methomyl, lambda-cyhalothrin da-cyolotrin, chlorpyrifos, spinosad, chlorantraniliprole caused a significant reduction in the number of living males and females, after 24 hours, all the active agents differed from the control treatments and in the 48 hours they caused 100% mortality for males, females and total adults. The evaluation, 96 hours after showed that there was no mortality in the treatment containing only the food attraction in the absence of insecticides.

The active ingredients methomyl, lambda-cyhalothrin and spinosad associated with the commercial food attraction Noctovi[®] 43sb, promoted 100% mortality of the insect population faster than the other molecules tested. The mean time in hours observed for mortality of *S. frugiperda* males, females and adults (couples) were 2.71 \pm 1.88, 1.41 \pm 0.40, 2.06 \pm 0.94, 1.69 \pm 0.28, 2.04 \pm 0.28, 1.86 \pm 0.19, 5.29 \pm 2.13, 2.32 \pm 0.36 and 3.80 \pm 1.12, respectively, for three most promising actives under the conditions studied (Figure 1).

Table 3. Mortality (mean ± standard error) of males, females and total adults (males + females) of *S. frugiperda*, because of 6 insecticides/chemical groups associated with food attractants under laboratory conditions. UFGD, Dourados, Mato Grosso do Sul, Brazil, 2019

Treatments	Time (hours) ⁽¹⁾										
	0.25	0.5	1	2	4	6	12	24	36	48	96
<i>Males</i>											
Water+honey (10%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A
Noctovi® 43sb	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A
Methomyl (2%)	33.3±0.21A	33.3±0.21A	50.0±0.22B	83.3±0.17B	83.3±0.17 C	83.3±0.17BC	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Lambda-cyhalothrin (1%)	0.00±0.00A	16.7±0.17A	16.7±0.17AB	83.3±0.17B	100.0±0.00 C	100.0±0.00 C	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorpyrifos (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	50.0±0.22ABC	50.0±0.22ABC	50.0±0.22AB	66.7±0.21B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Spinosad (1%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	33.3±0.21AB	66.7±0.21BC	66.7±0.21ABC	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorantraniliprole (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	33.3±0.21ABC	83.3±0.17B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorfenapyr (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	16.7±0.17A	16.7±0.17AB	16.7±0.17AB	66.7±0.21B	83.3±0.17B	83.3±0.17B	100.0±0.00B	100.0±0.00B
C.V. % ⁽²⁾	12.97	15.56	16.15	18.56	19.53	21.26	15.69	11.58	6.89	0.00	0.00
<i>Females</i>											
Water+honey (10%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A
Noctovi® 43sb	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A
Methomyl (2%)	16.7±0.17A	16.7±0.17A	33.3±0.21A	66.7±0.21B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Lambda-cyhalothrin (1%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	33.3±0.21AB	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorpyrifos (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	16.7±0.17A	16.7±0.17A	50.0±0.22AB	83.3±0.17B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Spinosad (1%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	33.3±0.21AB	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorantraniliprole (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	16.7±0.17A	66.7±0.21B	83.3±0.17B	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorfenapyr (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	50.0±0.22AB	83.3±0.17B	100.0±0.00B	100.0±0.00B	100.0±0.00B
C.V. % ⁽²⁾	10.41	56.31	12.97	20.88	11.61	13.16	16.00	9.98	0.00	0.00	0.00
<i>Adults (males+females)</i>											
Water+honey (10%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A
Noctovi® 43sb	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A
Methomyl (2%)	25.0±0.13B	25.0±0.13B	41.7±0.15B	75.0±0.13 C	91.7±0.08B	91.7±0.08 CD	100.0±0.00 C	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Lambda-cyhalothrin (1%)	0.00±0.00A	0.08±0.08AB	0.08±0.08A	58.2±0.15BC	100.0±0.00B	100.0±0.00 D	100.0±0.00 C	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorpyrifos (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	33.3±0.14A	33.3±0.14AB	50.0±0.15B	75.0±0.13B	75.0±0.13B	100.0±0.00B	100.0±0.00B
Spinosad (1%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	33.3±0.14AB	83.3±0.11B	83.3±0.11 CD	100.0±0.00 C	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorantraniliprole (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.00±0.00A	50.0±0.15BC	83.3±0.11AB	100.0±0.00B	100.0±0.00B	100.0±0.00B	100.0±0.00B
Chlorfenapyr (2%)	0.00±0.00A	0.00±0.00A	0.00±0.00A	0.08±0.08A	0.08±0.08A	0.08±0.08AB	58.3±0.15B	83.3±0.11B	91.7±0.08B	100.0±0.00B	100.0±0.00B
C.V. % ⁽²⁾	11.44	13.01	14.29	19.65	16.46	18.03	15.19	10.41	13.76	0.00	0.00

Note. ⁽¹⁾Original data with averages followed by the same letter in the columns do not differ from each other by Tukey's test, at 5% probability. ⁽²⁾ C.V. % of data transformed into $\sqrt{x + 0.5}$.

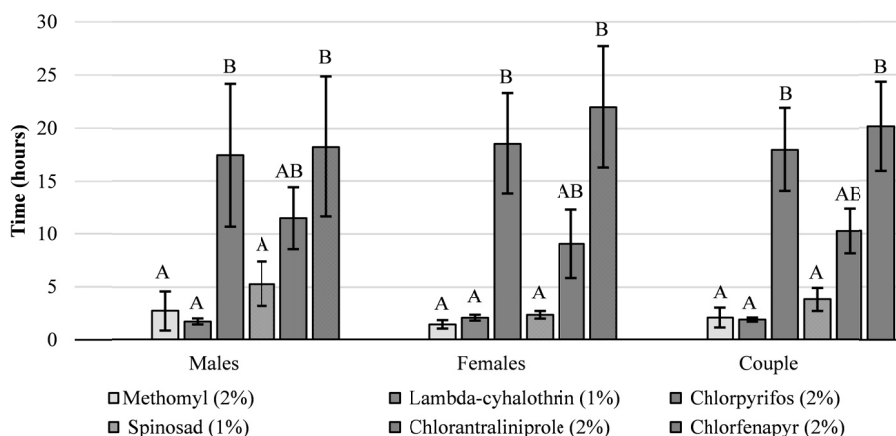


Figure 1. Time in hours for mortality (mean ± standard error) of male, female and adult (couple) *Spodoptera frugiperda* under controlled laboratory conditions. UFGD, Dourados, Mato Grosso do Sul, Brazil, 2019

4. Discussion

For the choice of an appropriate attraction, some factors should be considered, such as: cost, ease of application, attractiveness of adults, especially females and landing time associated with feeding, because the greater the contact of the sensory organs of insects with the bait, the greater the effectiveness of the associated insecticide (França et al., 2009).

Monitoring through food attractions is considered important because it is directly related to the primary instinct of these insects, a hypothesis would be that females need protein compounds to reach their sexual maturity (Nakano et al., 1981). The most commonly used food attractions are sugarcane molasses, fruit juice, brown sugar or pheromones (Nascimento & Carvalho, 1998).

In studies conducted by France et al. (2009), *Neoleucinodes elegantalis* (Lepidoptera: Crambidae) adults responded differently to the assessed attractions and parameters, with greater emphasis on sucrose and honey. Thus, it is expected that attractive baits with food stimulants make pest management by manipulating behavior an efficient tool and contribute to reduce the amount and increase the efficiency of pesticides applied in agricultural production systems. However, few studies on the use of attractive baits in the management of lepidoptera have been developed, and the greatest number of studies and information related to the use of baits in the management of diptera, such as fruit flies (Potts, 1999).

The baits may play a very important role in attracting insects, especially females responsible for reproduction. Research on the time to start and duration that adults spend to feed on these baits is fundamental, since it defines the amount of ingested product, potential for contamination and deleterious effect on the species (Potts, 1999; Borges et al., 2015).

Two main factors that should be considered in the choice of attractions for the formulation of toxic baits are: the attractive capacity, favoring the approach of the insect to the bait, and the phage stimulant effect or food response, increasing the consumption of bait that results in intoxication of individuals (Vargas et al., 2002; Pelz et al., 2005). The development of tactics for pest management based on manipulation of behavior has been very promising (Cook et al., 2007; Witzgall et al., 2008, 2010). Chemical substances involved in behavioral management, such as food stimulants and semi-chemicals, can become excellent auxiliary tools in pest control (Fosrter & Harris, 1997).

The use of baits is an important tool in IPM, especially in decision making to control certain pests. However, with toxic baits a mortality factor is added, where a synthetic insecticide is usually used (Arruda-Gatti & Ventura, 2003).

Papa et al. (2003) report the use of lures with insecticide cartape, associated with sugar, were effective in controlling adults of the pink cotton caterpillar, *Pectinophora gossypiella* (Lepidoptera: Gelechiidae). In relation to other lepidoptera, there is an indication for the control of moths in cotton and soybean with the application of a mixture of molasses, water and methomyl insecticide applied to the plants in bands with distances between them (Gallo et al., 2002).

In the management of *N. elegantalis* in tomato cultivation, toxic bait applications can contribute to the reduction of insecticide use and production costs, as well as benefit the environment and natural enemies, compared to conventional insecticide application systems (France et al., 2009). One of the advantages of toxic lures is the benefit to the environment, because they have less influence on natural enemies, because they are not applied in the total planting area, compared to the use of chemical insecticides (Gravena & Benvenga, 2003; Galli et al., 2004).

5. Conclusions

The honeydew (10%) and Noctovi[®] 43sb food attractions were more efficient in relation to feeding time for both females and all adults of *S. frugiperda*.

The highest number of landings was observed in the Noctovi[®] 43sb treatment in females and total adults.

The active ingredients methomyl, lambda-cyhalothrin and spinosad associated with food attractiveness are promising toxic baits for the management of fall armyworm.

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