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Growth Inhibitory Activities and Feeding Deterrence of Solanaceae-Based Derivatives on Fall Armyworm

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Abstract: *Spodoptera frugiperda* is a pest of worldwide importance, responsible for significant economic losses, mainly in maize crops. The use of botanical derivatives emerges as a promising alternative to control this insect pest. In this work, we evaluated the effect of ethanolic extracts (EE) and semi-purified fractions of *Acnistus arborescens* and *Datura stramonium* (Solanaceae) on the biological development of *S. frugiperda* and the effects of the semi-purified fractions on feeding behavior of 4th instar caterpillars. Crude extracts and fractions caused lethal and sublethal effects, namely increasing both duration of larval and pupal stages as well as deformities in adults, and decreasing weight of pupae. In turn, the effects on feeding deterrence were more pronounced in treatments with *A. arborescens* fractions. Our results highlight the potential of EE from solanaceous species as a source of allelochemicals that can be used in the integrated management of *S. frugiperda*.

Keywords: *Acnistus arborescens*; botanical insecticides; *Datura stramonium*; *Spodoptera frugiperda*

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1. Introduction

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is a polyphagous pest species [1] widely distributed in different agricultural production systems in America, Africa, and Asia [2–6]. The main methods for its control in maize crops, in which *S. frugiperda* is considered a key pest, is the use of synthetic insecticides [7] and genetically modified plants that express the insecticidal toxins of *Bacillus thuringiensis* (*Bt* events) [8,9]. However, considerable failures in the control and selection of resistant populations of this noctuid have already been recorded in Brazil due to the high selection pressure exerted by both methods [10–13]. Thus, it is necessary for the development of new control strategies compatible mainly with chemical and biological methods to be incorporated into integrated management programs in the framework of *S. frugiperda* management.

In this context, new control measures for the management of *S. frugiperda* have been investigated, such as the use of biological and botanical products [7,14–17]. Botanical insecticides are elaborated based on compounds (allelochemicals) from the secondary metabolism of plants, which is mainly responsible for plant defense against herbivory [18]. Research on the use of allelochemicals in pest control has increased considerably due to the need for products that are less persistent in the environment and in foods, less toxic to mammals, and more selective to beneficial organisms [19–21]. In the management of insect pests, botanical insecticides can be used directly in the form of homemade preparations, extracts, powders, or essential oils, or even to obtain active compounds (model prototypes) [21]. These derivatives present rapid degradation by the action of light and

temperature; thus, with low permanence in the environment and despite the need for a larger number of applications, they become advantageous since they do not leave residues in agro-food products [20,22,23].

Studies show that some species from tropical regions produce a wide range of secondary metabolites with bioactivity against insect pests [24–28]. Solanaceae is among the main promising botanical families already studied, which has a wide distribution in the tropics and contains species rich in secondary metabolites [29–32], some of which have already been reported to have bioactivity against insects [33–35]. Nicotine is the main bioactive component of Solanaceae *Nicotiana tabacum* L. and *Nicotiana rustica* L., and it was the first and most important alkaloid with insecticidal activity to be used extensively [18,36].

Botanical derivatives obtained from different solanaceous species have shown suitability for use in pest management programs [37–40]. In a comprehensive screening (38 extracts from 25 different tropical species), ethanol extracts (EE) of neotropical solanaceous *Acnistus arborescens* (L.) Schltdl and *Datura stramonium* L. were identified as promising against *S. frugiperda*, with two withanolides glycosides (22R)-1-Oxo-3beta-(beta-D-glucopyranosyloxy)-14,20,22,27-tetrahydroxyergosta-5,24-diene-26-oic acid delta-lactone and withanoside XI were noted in the most promising fractions [35]. *A. arborescens* is a native shrub distributed in the northeastern, southeastern, and southern regions of Brazil [41], abundant in vitanolides with cytotoxic activities [42–44]. However, *D. stramonium* is found in most temperate regions worldwide and has a large number of tropane-type alkaloids distributed throughout the plant [45], while some plant structures even have activity in insects [46–48]. However, the effects of such derivatives on biological, behavioral, and demographic parameters of pest arthropods have been little explored.

This study aimed to evaluate the effects of EE and semi-purified fractions of *A. arborecens* and *D. stramonium* on biological parameters and feeding behavior of fall armyworm. The experiments were carried out in laboratory tests using a commercial insecticide based on limonoids [Azamax® 1.2 EC (UPL Brasil, Ltd., Campinas, São Paulo, Brazil)] as a positive control, and two negative controls [acet.:met. 1:1 (*v*/*v*) and water].

2. Materials and Methods

2.1. Insects

The population of *S. frugiperda* used in the bioassays was obtained from rearing kept under laboratory conditions (temperature 25 ± 1 °C, RH 60 ± 10%, and a photophase of 14 h). Whenever necessary, populations were reintroduced from the field to avoid inbreeding. For maintenance, caterpillars were placed individually in 50 mL plastic containers and fed an artificial diet [49] until pupa formation. The adults that emerged were distributed in PVC cages where they received a 10% (*w*/*v*) honey solution as a food source.

2.2. Extracts and Fractions

Leaves of *A. arborescens* were collected from specimens cultivated at the Center for Nuclear Energy in Agriculture at the University of São Paulo (CENA/USP) (22°42′30.2″ S; 47°38′38.2″ W), in the municipality of Piracicaba, São Paulo State, Brazil, while leaves of *D. stramonium* were obtained at Sítio Retiro (21°12′03.5″ S; 45°09′54.5″ W), in the municipality of Lavras, Minas Gerais State, Brazil. A specimen of each species was deposited in the ESA herbarium of the Department of Biological Sciences of Luiz de Queiroz College of Agriculture (ESALQ/USP), under number D. S. Gissi 46 and A. F. Lima 01, respectively.

After collection, the leaves were washed under running water and dried in an oven with forced air circulation at 40 °C for a period of 72 h and then crushed in a knife mill (Thomas Scientific, Philadelphia, PA, USA) and stored in hermetically closed glass bottles until use.

Crude EE were obtained by the method of cold maceration in solvent (ethanol) grade analysis (99.5%) at the ratio of 1:5 (*w*/*v*) [35,50]. Initially, the powder from the dried leaves was mixed with the solvent and subjected to constant agitation for 3 min, kept at rest for

3 days and filtered through filter paper, after this period. This procedure was repeated three times, totaling three filtrations. After each filtration, solvents of the filtered samples were eliminated using a rotary evaporator at 50 °C and pressure of −600 mmHg, obtaining the crude EE of both plant species.

The crude EE were submitted to the liquid–liquid separation process to obtain semi-purified fractions [35]. For this, the EE were resuspended in water and methanol (1.5:1, *v*/*v*) and partitioned in a separating funnel. The separation process began with 500 mL of the non-polar solvent hexane, and after three filtrations the solubilized sample of the crude extract was subjected to a rotary evaporator until obtaining the aqueous fraction, which was subsequently partitioned with dichloromethane solvent. Three fractions were obtained: hexane, dichloromethane, and aqueous. In a previous study, the dichloromethane fraction proved to be more active on *S. frugiperda* and thus it was selected for this study [35].

2.3. Bioassays

All bioassays were carried out under controlled laboratory conditions (temperature 25 ± 1 °C, RH 60 ± 10%, and a photophase of 14 h) in a completely randomized design.

2.3.1. Effects of Crude Ethanolic Extracts of *A. arborescens* and *D. stramonium* on Biological Parameters of *S. frugiperda*

The effects of EE were evaluated at a concentration of 4000 mg kg^{-1}, defined based on a previous study [35]. The EE were solubilized in 6 mL of solvent solution [acetone: methanol (1:1, *v*/*v*)] and incorporated into 600 g of artificial diet [49] at a temperature below 50 °C to avoid the degradation of thermolabile compounds [35,50]. As a positive control, we used a commercial insecticide based on limonoids [Azamax® 1.2 EC (UPL Brasil, Ltd., Campinas, São Paulo, Brazil)] incorporated at the recommended concentration (4000 mg kg^{-1}) for the control of *S. frugiperda* in corn in Brazil [51]. Furthermore, two negative controls were established: distilled water and acetone + methanol (1:1, *v*/*v*), both at the same volume (6 mL), used for solubilization of the positive control and the extracts, respectively.

After incorporating the treatments into the artificial diet [49], 6 mL of the diet were deposited in flat-bottomed glass tubes (8.5 cm of height × 2.5 cm of diameter) containing a newly hatched caterpillar (<24 h of age) of *S. frugiperda*. Ten replicates per treatment were used, each replicate represented by 8 tubes (n = 80 caterpillars).

Assessments were performed daily until the emergence of adults. The evaluated parameters were: mortality and duration of the larval and pupal stages; weight of pupae at 24 h; and percentage of pupae and deformed adults. The deformed pupae were considered with incomplete formation and by the retention of the remaining exuvia of the last larval instar. While deformed adults were mainly characterized by malformations in the fore and hind wings.

2.3.2. Effects of Dichloromethane Fractions on Biological Parameters of *S. frugiperda*

In this bioassay, dichloromethane fractions, at their respective median lethal concentrations (LC_{50}) previously estimated for *A. arborescens* (3694 mg kg^{-1}) [35] and for *D. stramonium* (4088 mg kg^{-1}; CI 95% = 2.682–5.341 mg kg^{-1}; n = 504; slope ± SE = 2.88 ± 0.66 ($p < 0.0001$); $\chi^2 = 0.0005$; df = 5; h = 2.11), were incorporated into 600 g of artificial diet [49]. For that, the same procedures detailed in the previous subitem (2.3.1) were adopted, but using only a negative control (acetone: methanol) totaling three treatments, which consisted of 12 repetitions containing 10 tubes each, totaling 120 caterpillars per treatment.

2.3.3. Effects of Dichloromethane Fractions on Food Consumption of *S. frugiperda*

The effects of dichloromethane fractions on food consumption of 4th instar *S. frugiperda* caterpillars were evaluated in a no-choice bioassay. For that, the artificial diet was treated with concentrations equivalent to the LC_{25}, LC_{50}, and LC_{90} (concentrations necessary to kill 25, 50, and 90% of the population, respectively) of each fraction, calculated as reported in a previous study [35]. Values equivalent to 1966 were used: 3694 and 8739 mg kg^{-1}, respectively, for LC_{25}, LC_{50}, and LC_{90} of *A. arborescens*; while for *D. stramonium* values were 2025 mg kg^{-1} (LC_{25}), 4088 mg kg^{-1} (LC_{50}), and 10,670 mg kg^{-1} (LC_{90}). The fractions were added to the diet according to the method presented in subitem 2.3.1, except for the amount of artificial diet to incorporate into the fractions, which was 150 g, in this case.

The diets prepared and treated with the fractions were poured into plastic boxes (11 × 11 × 3.5 cm) of the Gerbox type (J Prolab® Ind. e Com. de Produtos para Laboratório Ltd.a., São José dos Pinhais, Paraná, Brazil), and were cut into pieces of 1.5 cm × 1.5 cm to be offered to the caterpillars after 24 h. Then, pieces of the treated diet were weighed and placed in the center of Petri dishes (5.5 cm of diameter). Caterpillars in the 4th instar were deprived of food for 6 to 7 h before the start of the experiment. The most active caterpillars (uniform weight and with active walking) were selected for the bioassay, which were individualized in the center of each plate containing the respective treatment. The bioassay consisted of nine treatments and 25 repetitions, each repetition consisting of a Petri dish with a 4th instar caterpillar.

After 24 h, the artificial diet remaining in the samples was weighed to calculate food consumption of the caterpillars based on the difference between the initial and final weight. To determine water loss of food, an aliquot corresponding to 10 whole pieces was kept and weighed at the beginning and at the end of the experiment. The average weight of the 10 pieces was considered the initial weight of each piece of artificial diet offered to the caterpillars.

2.4. Data Analyses

Data on the proportion of larval and pupal mortality and deformed pupae and adults were analyzed using a generalized linear model (GLM) [52] with a quasi-binomial distribution. In cases of significant differences between treatments, multiple comparisons were performed (Tukey's post hoc test, $p < 0.05$) using the "glht" function of the Multicomp package with adjustment of p values.

Data on duration of the larval and pupal stages, pupal weight, and food consumption of caterpillars were first tested for assumptions of normality (Shapiro-Wilk test) and homogeneity (Bartlett test) of variances. If necessary, the data were transformed using the "boxcox" function [53] of the MASS package. However, in cases where the transformation did not satisfy the assumptions, the data were analyzed using GLM with gamma distribution with multiple comparisons (Tukey's *post hoc* test, $p < 0.05$) or the treatments were compared by ranking in the Kruskal–Wallis test, except for the data referring to bioassay 2.3.2, which were analyzed using the Wilcoxon test [54]. The quality of the fit of the data to the GLM model was performed using the half-normal probability graph with simulation envelope of the HNP package [55].

All analyses were performed using the Statistical Software R, version 4.2.2 [56].

3. Results

3.1. Effects of Crude Ethanolic Extracts of A. arborescens and D. stramonium on Biological Parameters of S. frugiperda

At a concentration of 4000 mg kg^{-1}, crude EE of *D. stramonium* and *A. arborescens* increased larval mortality rates in *S. frugiperda*, without causing any difference between both pant species (Table 1). Nevertheless, mortality values were lower than the positive control (Azamax® 1.2 EC), which caused total mortality of the caterpillars ex-posed. The duration

of the larval stage of *S. frugiperda* was approximately doubled in treatments consisting of EE of *A. arborescens* and *D. stramonium* compared to the negative controls (Table 1).

Table 1. Effects of crude ethanolic extracts of *Acnistus arborescens* and *Datura stramonium* at a concentration of 4000 mg kg^{-1} on the biological development of *Spodoptera frugiperda*.

Treatment	Larvae		Pupae				Adults
	Mortality (%) [1]	Duration (days) [2]	Mortality (%) [1]	Duration (days) [2]	Weight (mg) [3]	Deformity (%) [1]	Deformity (%) [1]
Acnistus arborescens	62.5 ± 5.45 a	33.9 ± 0.54 a	36.7 ± 8.94 a	13.9 ± 0.34 a	173.9 ± 6.57 b	13.3 ± 6.31	15.8 ± 8.59
Datura stramonium	77.5 ± 4.70 a	32.5 ± 0.75 a	44.4 ± 12.10 a	12.8 ± 0.26 b	123.9 ± 9.89 c	16.7 ± 9.04	20.0 ± 13.33
Negative control (acet.:met., 1:1)	6.3 ± 2.72 b	17.9 ± 0.28 b	2.7 ± 1.87 b	12.3 ± 0.13 b	210.8 ± 2.66 a	0.00 ± 0.00 *	5.5 ± 2.68
Negative control (water)	6.3 ± 2.72 b	18.1 ± 0.25 b	4.0 ± 2.28 b	12.1 ± 0.11 b	211.3 ± 2.50 a	0.00 ± 0.00 *	5.5 ± 2.72
Positive control (Azamax® 1.2 EC)	100.0 ± 0.00 *	-	-	-	-	-	-
	$F_{3, 316} = 52.48$; $p < 0.0001$	$F_{3, 33} = 434.56$; $p < 0.0001$	$F_{3, 194} = 12.56$; $p < 0.0001$	$F_{3, 31} = 16.71$; $p < 0.0001$	$F_{3, 34} = 53.79$; $p < 0.0001$	$F_{1, 46} = 0.09$; $p = 0.759$	$F_{3, 170} = 1.29$; $p = 0.279$

* Not included in the analysis due to lack of variability; [1] Means analyzed with GLM with quasi-binomial distribution, which indicate differences between treatments when followed by different letters in the columns (by Tukey's *post hoc* test; $p < 0.05$); [2] Means analyzed with GLM with gamma distribution, which indicate differences between treatments when followed by different letters in the columns (by Tukey's *post hoc* test; $p < 0.05$); [3] Means followed by different letters in the columns indicate a significant difference between treatments by the Tukey test ($p < 0.05$) (original data transformed using the BOX-COX method).

In the pupal stage, the EE of both Solanaceae species evaluated presented lethal effects (Table 1) without, however, any difference between both. On the other hand, the pupal stage duration of *S. frugiperda* was longer in the treatment consisting of EE of *A. arborescens* compared to *D. stramonium* and the negative controls, which did not differ from each other (Table 1). Nevertheless, the treatment with EE of *D. stramonium* caused a more pronounced reduction in the pupal weight, differing from the treatment with EE of *A. arborescens*, which showed a reduction of about 40 and 20%, respectively, in relation to the pupal weight in the negative controls. The EE did not affect the proportion of deformed pupae and adults (Table 1).

3.2. Effects of Dichloromethane Fractions on Biological Parameters of *S. frugiperda*

Dichloromethane fractions of *A. arborescens*, at the medium lethal concentration (LC_{50}), caused 100% mortality of the caterpillars exposed (Table 2). In addition, dichloromethane fractions of *D. stramonium* increased in the larval stage duration with the surviving caterpillars taking roughly twice as long to reach the pupal stage when compared to the control.

Table 2. Effect of dichloromethane fractions from crude ethanolic extracts of *Acnistus arborescens* and *Datura stramonium*, at the respective medium lethal concentrations (LC_{50}), on the biological development of *Spodoptera frugiperda*.

Treatment	Larvae		Pupae				Adults
	Mortality (%) [1]	Duration (days) [2]	Mortality (%) [1]	Duration (days) [2]	Weight (mg) [2]	Deformity (%) [1]	Deformity (%) [1]
Acnistus arborescens	100.0 ± 0.00 *	-	-	-	-	-	-
Datura stramonium	83.2 ± 3.44 a	42.1 ± 1.73 a	10.5 ± 7.23	13.3 ± 0.62 a	161.6 ± 13.13 b	40.0 ± 11.24 a	27.3 ± 14.08 a

Negative control (acet.:met., 1:1)	8.3 ± 2.53 b	21.0 ± 0.16 b	9.1 ± 2.75	11.8 ± 0.15 b	255.6 ± 3.46 a	8.3 ± 2.64 b	1.8 ± 1.29 b
	$F_{1, 237} = 151.59$; $p < 0.0001$	W = 2160; $p < 0.0001$	$F_{1, 127} = 0.038$; $p = 0.846$	W = 758.5; $p = 0.005$	W = 31.0; $p < 0.0001$	$F_{1, 127} = 11.33$; $p = 0.001$	$F_{3, 118} = 8.58$; $p = 0.004$

* Not included in the analysis due to lack of variability; [1] Means analyzed with GLM with quasi-binomial distribution, which indicate differences between treatments when followed by different letters in the columns (by Tukey's *post hoc* test; $p < 0.05$); [2] Means followed by different letters in the columns indicate a significant difference between treatments by the Wilcoxon test ($p < 0.05$).

Dichloromethane fractions of EE of *D. stramonium* did not cause a lethal effect in the pupal stage at LC_{50} previously estimated. However, a sublethal effect was observed, including an increase in the stage duration, weight decrease in pupae, and an increase in the proportion of pupae and deformed adults (Table 2).

3.3. Effects of Dichloromethane Fractions on Food Consumption of *S. frugiperda*

The concentrations tested (equivalent to LC_{25}, LC_{50}, and LC_{90}) of dichloromethane fractions of EE of both solanaceous species evaluated significantly decreased food intake of *S. frugiperda* caterpillars in comparison to the negative controls (acetone + methanol and distilled water), treatments in which the average consumption was 51.7 mg and 32.6 mg, respectively (Table 3). The lowest food consumption was observed in the treatments with EE of *A. arborescens* at concentrations equivalent to the LC_{90} and LC_{50}, which were even lower in relation to the positive control (Azamax® 1.2 EC; 17.5 mg) and by treatments with *D. stramonium*. The caterpillars consumed equally the diets treated with EE of *D. stramonium*, regardless of the concentration (varying values from 15.8 to 41.7 mg; Table 3).

Table 3. Means (±standard error) of diet weight (mg) consumed by 4th instar caterpillar of *Spodoptera frugiperda*, after 24 h of exposure, in a no-choice test with different concentrations of dichloromethane fractions of ethanolic extracts of *Acnistus arborescens* and *Datura stramonium* incorporated into an artificial diet.

Treatment	Concentration (mg kg^{-1})	Consumption (mg) [1]
Acnistus arborescens	8739 (=LC_{90})	2.4 ± 1.02 e
	3694 (=LC_{50})	3.5 ± 0.97 de
	1966 (=LC_{25})	6.2 ± 1.48 cd
Datura stramonium	10,670 (=LC_{90})	41.7 ± 19.90 b
	4088 (=LC_{50})	15.8 ± 5.02 bc
	2025 (=LC_{25})	16.0 ± 2.03 b
Negative control (acet.:met., 1:1)		51.7 ± 9.03 a
Negative control (water)		32.6 ± 3.48 a
Positive control (Azamax® 1.2 EC)		17.5 ± 7.93 bc
$X^2 = 95.117$; df = 8; $p < 0.0001$		

[1] Means followed by different letters in the columns indicate a significant difference between treatments by the Kruskal–Wallis test ($p < 0.05$).

4. Discussion

Our results showed pronounced inhibitory effects on the development and food deterrence of EE and semi-purified fractions of *A. arborescens* and *D. stramonium* for *S. frugiperda*, a pest species distributed worldwide and of importance in different agricultural production systems. To date, no studies have investigated the influence of EE of these neotropical Solanaceae on biological parameters of *S. frugiperda*. The knowledge of sublethal effects of botanical insecticides is very important for the development of management programs for this noctuid pest. Sublethal effects can be expressed by the longer duration of the larval stage of the insect and in this case, in the field, it is exposed to the attack of parasitoids, predators, and entomopathogens for a longer time. Furthermore, the insects

that emerged may be out of synchrony with the natural population (not exposed to the products) and thus mating is limited [57], which may, consequently, decrease the number of generations with minimization of the risks of outbreaks of pest populations [58].

The effects of several plant extracts on biological parameters of *S. frugiperda* have been reported, such as the action of crude derivatives and acetogenins isolated from Annonaceae [50,58–60], essential oil of *Lippia sidoides* Cham. (Verbenaceae) [16], fractions of the Meliaceae *Trichilia pallida* Sw., *Trichilia pallens* C.DC. and *Toona ciliata* M. Roem. [61] and crude leaf extracts of *Actinostemon concolor* (Spreng.) Müll. Arg. (Euphorbiaceae) [62]. In our bioassays, the sublethal effects observed on biological parameters of *S. frugiperda* may be due to reduced food intake because of the significant food deterrent effect, or even due to post-ingestive physiological effects, since mortality occurred in all caterpillars submitted to dichloromethane fractions of EE of *A. arborescens* as well as a high rate of deformities of pupae and adults of caterpillars exposed during the entire larval stage to derivatives of *D. stramonium*. These deformities were characterized mainly by retention of the exuvia remaining from the last larval instar and malformations of the anterior and posterior wings, effects which can influence the biological fitness and population growth of the target pest. The longer larval stage of Lepidoptera observed in this study can be attributed to the presence of growth inhibitors, food deterrents, and/or toxic substances existing in the extracts [63], or even a compensatory mechanism for inadequate nutrient absorption such as maximization of protein digestion [62], which can negatively affect growth and development of insects [64]. However, further studies are needed to better understand action mechanisms of allelochemicals of these two Solanaceae in *S. frugiperda*.

Food deterrence is classified into primary and secondary. The primary occurs when the compound affects the food by acting on chemoreceptors, while the secondary occurs when the insect ingests the compound and thus causes secondary toxic effects [65]. Therefore, primary food deterrence causes a rapid interruption in feeding, as observed for the dichloromethane fractions of EE of *A. arborescens* and *D. stramonium*. This result is advantageous as the reduction in feeding in pest species tends to reduce the damage caused to the crops [58], and is usually measured in laboratory tests with or without choice with periods of evaluation ranging from 24 to 72 h [66]. Corroborating our results, crude leaf extracts of *D. stramonium* at a concentration of 3007 mg L^{-1} (incorporated in disks of flour) on insects of 1–3 days of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), during 72 h, caused a food deterrence index of 97.27%, which resulted in a low relative consumption rate (0.081 mg mg^{-1}) and growth (0.022 mg mg^{-1}) when compared to the control (0.255 and 0.143 mg mg^{-1}, respectively) [47].

The lethal effect observed in pupae in treatments with crude extracts corroborates other studies using derivatives of different species of Solanaceae. For instance, crude extracts of *Withania somnifera* L. caused mortalities in pupae of *Spodoptera litura* Fabr. (Lepidoptera: Noctuidae) [67], while the methanolic extract of fruits of *Solanum xanthocarpum* Schrad. and Wendl. in contact with pupae of *Aedes aegypti* (L.) (Diptera: Culicidae) caused more than 50% of mortality [68]. In addition, the aqueous extract and nanoparticles of *Solanum mammosum* L. have larvicidal activity for *A. aegypti*, probably due to the high diversity of compounds in the species [37].

Allelochemicals with sublethal action on solanaceous plants can limit the growth of pest insect populations in the field. Glycoalkaloids, such as solasonine, interact with cells of the midgut and adipose tissue, which can generate disturbances in the metabolism and induce oxidative stress in the caterpillars of *Galleria mellonella* L., with a possible weakening of the population [40,69]. In our work, the most pronounced sublethal effects were the increase in the larval and pupal stages, the decrease in pupae weight, and the reduction in diet consumption treated with *A. arborescens* and *D. stramonium* derivatives. Such botanical derivatives caused a lethal effect and inhibited weight gain in newly hatched *S. frugiperda* caterpillars, specifically due to the presence of withanolide glycosides in *A. arborescens* derivatives [35].

The bioactivity of Solanaceae in the biological development of pests may vary depending on the plant species. In commercially important species, such as pepper (*Capsicum annuum* L.), eggplant (*Solanum melongena* L.) and tomato (*Solanum lycopersicum* Mill.), this bioactivity affected the fitness of *S. frugiperda* differently, inhibiting the full development of the pest in eggplant [70]. The effects on the biology and food deterrence in *S. frugiperda* of the plant species tested in this study have not been previously studied. Depending on the concentration used, EE of *D. stramonium* leaves caused lethality in females of *Tetranychus urticae* (Koch) (Acari: Tetranychidae) [71], decreased the nutritional indices of *T. castaneum* [47], and showed larvicidal and inhibitory effects of oviposition in *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) [48]. On the other hand, crude EE of branches and leaves of *A. arborescens* at 2500 mg kg^{-1} decreased viability of *Zabrotes subfasciatus* (Boh.) (Coleoptera: Chrysomelidae) [39].

In this work, the pronounced insecticidal and insectistatic effects of EE of *A. arborescens* and *D. stramonium* are reported, as well as the significant effect on food deterrence of their fractions on *S. frugiperda* under laboratory conditions. However, future studies should be carried out under semi-field and field conditions to evaluate effectiveness and interaction with the environment of EE of *A. arborescens* and *D. stramonium*, as well as the association of such derivatives with other *S. frugiperda* management strategies. Furthermore, it is necessary to conduct studies to evaluate the effect of such derivatives on non-target organisms such as natural enemies and pollinators, as there is a lack of such information in the literature.

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