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Research Article

Selectivity and effects of essential oils on the egg parasitoid *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) reared on *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) and *Corcyra cephalonica* (Stainton, 1866) (Lepidoptera: Pyralidae)

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Abstract. *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) is a polyphagous and cosmopolitan pest that damages economically important crops. Efficient management requires integrated strategies, with emphasis on biological control. *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) is an egg parasitoid of *Spodoptera* spp., but it can also develop in other lepidopterans, such as *Corcyra cephalonica* (Stainton, 1866) (Lepidoptera: Pyralidae), making it a promising alternative host. The effectiveness of biological control depends on its compatibility with other tactics, such as essential oils (EOs) with insecticidal properties. This study evaluated the selectivity and effects of *Syzygium aromaticum* (L.) Merr. & L.M.Perry, *Cymbopogon citratus* DC. Stapf., *Schinus terebinthifolius* Raddi, *Cordia verbenacea* DC., *Baccharis dracunculifolia* DC., and *Callistemon viminalis* (Sol. ex Gaertn.) G. Don. EOs on *T. remus* reared on *S. frugiperda* and *C. cephalonica*. The longevity and parasitism of the parental and F1 generations, and the emergence rate and sex ratio of F1 and F2 generations, were assessed. Toxicity was classified according to IOBC standards. *Baccharis dracunculifolia, C. citratus*, and *S. aromaticum* showed selectivity for F1 parasitism, but not for the parental generation. Except for *B. dracunculifolia*, all oils were selective for F1 emergence in *S. frugiperda*. The longevity of parasitoids reared on *C. cephalonica* was lower than that observed in *S. frugiperda*. In the adult stage, *S. terebinthifolius, C. verbenacea, C. viminalis*, and *C. citratus* exhibited selectivity for *T. remus* reared on *S. frugiperda*, whereas in *C. cephalonica*, only *C. viminalis* was selective. No effects were observed on F2 parameters. The results indicate the potential for integrating the use of EOs with *T. remus* in the management of *S. frugiperda.*

Keywords: Fall armyworm, Rice moth, Biological control, Botanical extracts, Integrated Pest Management.

Introduction

Spodoptera frugiperda (J. E. Smith, 1797) (Lepidoptera: Noctuidae) is one of the most devastating pests of the Noctuidae family. It is a polyphagous and cosmopolitan pest characterized by a broad host range, strong migratory ability, rapid spread, and a high reproductive rate. In Brazil, chemical control remains the predominant management tactic, but its intensive use has selected for resistant populations, increasing costs and causing adverse environmental impacts (Fortes et al. 2023; Tang et al. 2025).

The search for management tools with lower impact on the agroecosystem has led farmers to adopt Integrated Pest Management (IPM), which integrates different control tactics (Angon et al. 2023), among them biological control. This control strategy consists of regulating the number of individuals of a particular plant or animal species (Pratissoli et al. 2019) below the economic damage level by natural enemies, including pathogens, predators, herbivores, or parasitoids (Parra 2019). Parasitoids are the most widely used control agents, playing a fundamental role in reducing pest insect populations (Pratissoli et al. 2019).

Telenomus remus (Nixon, 1937) (Hymenoptera: Platygastridae) is an egg parasitoid with great potential for controlling *Spodoptera* spp. (Fortes et al. 2023). However, *T. remus* is only reared on a small scale due to the costs and difficulties of rearing it on the natural host, *S. frugiperda*, which exhibits larval cannibalism (Pomari-Fernandes et al. 2015; Queiroz et al. 2017a). To promote the mass rearing of *T. remus*, it is necessary to use alternative hosts that have a high egg production, are easy to multiply, and provide adequate nutritional quality for parasitoid development. *Telenomus remus* is capable of developing in eggs of *Corcyra cephalonica* (Stainton, 1866) (Lepidoptera: Pyralidae) (Pomari-Fernandes et al. 2015). As a result, *C. cephalonica* becomes a promising alternative host, easily reared in the laboratory and with lower costs compared to *S. frugiperda* (Li et al. 2023).

Although the use of parasitoids is an important tool in IPM, efficacy depends on the use of tactics selective to these organisms. The use of plant metabolites with insecticidal effects, such as essential oils (EOs), is a promising control tactic (Hassan et al. 2023). EOs are produced by several botanical families, including Anacardiaceae, Asteraceae, Boraginaceae, Myrtaceae, and Poaceae. Studies with the oils of *Syzygium aromaticum* (L.) Merr. & L. M. Perry (Myrtales: Myrtaceae), *Cymbopogon citratus* DC. (Poales: Poaceae), *Schinus terebinthifolius* Raddi (Sapindales: Anacardiaceae), *Cordia verbenacea* DC. (Lamiales: Boraginaceae), *Baccharis dracunculifolia* DC. (Asterales: Asteraceae) and *Callistemon viminalis* (Sol. ex Gaertn.) G. Don. (Myrtales: Myrtaceae) have demonstrated insecticidal activity against *S. frugiperda* (Tagliari et al. 2010, Tirelli et al. 2010; Knaak et al. 2013; Cruz et al. 2014). However, EOs may not be selective and can negatively impact some groups of natural enemies (Lisi et al. 2025), potentially causing malformations and mortality or altering other biological characteristics in both adult and immature stages (Zanuncio et al. 2016; Parreira et al. 2018a; 2018b).

Thus, this study aimed to evaluate the selectivity and sublethal effects of selected plant EOs on the egg parasitoid *T. remus*, reared on both the natural host *S. frugiperda* and the alternative host *C. cephalonica*.

Material and Methods

Insects rearing and experimental conditions. *Spodoptera frugiperda* rearing was carried out using an artificial diet composed of protein components, vitamin solution, antimicrobials, carrageenan, and distilled water (Greene et al. 1976). The diet (±10 mL) was placed in plastic cups (50 mL), into which neonates (up to 24 hours old) were transferred. The cups were sealed with plastic lids and kept in plastic boxes in a climate-controlled room at 25 ± 1 °C, 60 ± 5% relative humidity, and a 12-hour photophase. The larvae remained on the artificial diet until pupation. After complete larval development, the pupae were removed and placed in Petri dishes, then transferred to polyvinyl chloride (PVC) cages lined with brown kraft paper, which served as an oviposition substrate. Adults were fed a honey-water solution (1:10) inside the cages. To collect the eggs, the kraft paper sheets with egg masses were removed from the adult cages, cut into strips, and placed in sealed 500 mL plastic cups covered with PVC film and lids. The cups containing eggs were maintained in a climate-controlled room until larval hatching, after which the neonates were transferred to artificial diet, starting a new generation of *S. frugiperda*.

For *C. cephalonica* rearing, the artificial diet consisted of wheat germ sterilized at 170°C for 30 min and brewer's yeast (Bernardi et al. 2000). The ingredients were homogenized and compacted into a plastic container (25 × 17 × 9 cm), into which 0.12 g of *C. cephalonica* eggs were subsequently distributed. The container was then sealed with a plastic lid fitted with a voile fabric-covered opening and kept in a climate-controlled room at 20 ± 1°C and 70 ± 10% RH without light until the emergence of the first adult. After the emergence of the first adult, the containers were transferred to a climate-controlled room at 25 ± 1°C, 70 ± 10% RH, and 12-h photophase, where adults were collected daily using a vacuum aspirator and transferred to cages made from PVC tubes (10 cm diameter × 21.5 cm height) covered with nylon mesh on the top, bottom, and inner surfaces to serve as an oviposition substrate for the moths. The cages were kept on trays to facilitate egg removal. The eggs were separated from the scales, gathered, and stored under refrigeration at 4–8°C until use.

Extraction of essential oils. The EOs of *S. aromaticum*, *C. citratus*, *S. terebinthifolius*, *C. verbenacea*, *B. dracunculifolia*, and *C. viminalis* were extracted by steam distillation. The extraction equipment used was a Marconi® distiller, model MA 480. The plant material was placed in a perforated metal basket, which was positioned in the equipment to keep it above the distilled water (5 L) present in the distiller's boiler. The water was then heated, and the plant material was subjected to a steam current directed through the equipment's condenser. As this mixture of oil and water vapor condensed, separation into layers occurred due to density differences, yielding the EO. The extraction period lasted approximately 8 hours, after which the EO was stored in sealed amber containers under refrigeration (4.0 ± 0.5°C) (Guerra et al. 2015).

Sublethal effects of essential oils on the biological characteristics of *T. remus*. To evaluate the effects on parasitoids, a 1% concentration of each plant species was applied. Newly emerged females of *T. remus* were placed in glass tubes covered with PVC film. Eggs of *S. frugiperda* adhered to paper strips (5 cm in length × 0.5 cm in width) were immersed for five seconds in the EOs solutions and placed on paper towels for 30 minutes to dry. Subsequently, *T. remus* females were exposed to these treated eggs for 24 hours. The females were kept inside the tubes, and the paper strips with eggs were transferred to new containers in a climatic chamber at 25 ± 1 °C, 70 ± 5% relative humidity, and a 12-hour photophase until the F1 generation. Newly emerged females from this generation, obtained from treated *S. frugiperda* eggs, were placed individually in glass tubes with drops of honey on the inner wall and exposed to strips of untreated *S. frugiperda* eggs for 24 hours. After this period, these females were kept inside the tubes, and the paper strips with eggs were transferred to new containers in a climatic chamber under the same conditions until the F2 generation. The experiment followed a completely randomized design with seven treatments (six EOs and one control) and eighteen replications (one female + one egg card per tube).

Selectivity to *T. remus* adults. According to International Organization for Biological and Integrated Control of Noxious Animals and Plants (IOBC) recommendations, the cages used were appropriately constructed for selectivity bioassays. The cages consisted of aluminum frames measuring 13 cm wide, 13 cm long, 2 cm heigh, with side holes (1 cm in diameter) for ventilation. Each hole was internally sealed with black cotton fabric, allowing gas exchange while preventing the escape of biological agents (Hassan et al. 2000). In addition to the ventilation holes on three sides of the cage, the fourth side contained a 3.5 × 1 cm opening through which egg cards of the host species were introduced for parasitism evaluation. Next to this opening, another was used to attach Duran tubes for parasitoid release. These openings were sealed and opened only during the introduction. The cages were closed with 169 cm², 2 mm-thick glass plates, secured with elastic bands. To prevent direct contact between the cage surfaces and the glass, noise-reducing foam was attached to the cages. During the bioassays, all cages were connected by a silicone tubing system linked to a vacuum pump, preventing vapor accumulation by maintaining constant ventilation.

Selectivity to adult parasitoids was assessed using *S. frugiperda* host eggs. The products were sprayed directly onto the glass plates of the cages, using a Vonder® airbrush and a Potter spray tower, to allow adult parasitoids to contact the treated surfaces. The upper and lower glass plates received applications of the products and the control at a 1% concentration, applied at a spray volume equivalent to 250 L/ha (Gladenucci et al. 2020). After drying, both glass plates were placed facing inward with the treated sides exposed. To ensure that parasitoids remained in the central area (7 × 7 cm), the outer edges of the glass were covered with black cardboard, defining the contact area between the parasitoids and the treated surface.

For tests with adult *T. remus*, 0.25 cm² of host egg cards were prepared per replicate. Eggs were attached to the cards using double-sided tape, then placed in Duran tubes sealed with plastic film. Pure honey was provided inside each tube as food for the parasitoids after emergence. Each treatment included five replicates, totaling 35 Duran tubes containing parasitized egg cards. After the parasitoids emerged, the tubes were connected to the treated cages.

Prior to connection, the tubes were wrapped in aluminum foil to keep them dark and encourage parasitoids to enter the attached cages. The plastic film was removed to release the parasitoids into the cages, allowing contact with the treated glass surfaces.

After colonization of the cages by parasitoids for each treatment, egg cards of the host species were offered for parasitism for three consecutive days. Egg cards with 3 cm² of host eggs were provided at 24, 48, and 72 hours. After 96 hours (on the fourth day), the cages were disassembled, and the exposed egg cards were collected, labeled by date and treatment, and stored in plastic bags for subsequent evaluation. The experiment followed a completely randomized design (CRD) with seven treatments (six EOs and one control) and five replicates per treatment.

Selectivity to *T. remus* pupae. For the evaluation of selectivity to parasitoids in the pupal stage, treatments were sprayed directly onto *S. frugiperda* and *C. cephalonica* eggs parasitized by *T. remus*. At this stage, 0.75 cm² of parasitized egg cards were sprayed directly. The eggs were 144–196 hours post-parasitism, corresponding to the pupal stage of the biological agents (Priyanka et al. 2023). The experiment followed a completely randomized design (CRD) with seven treatments (six EOs and one control) and five replicates per treatment. Using a Potter spray tower, 35 egg cards containing parasitoids in the pupal stage inside the host eggs were treated. After spraying, the cards were air-dried under natural conditions, individualized in sealed cages, and parasitoids were allowed to emerge and colonize the space. After 24 hours of emergence, 3 cm² egg cards of *S. frugiperda* were offered at 24, 48, and 72 hours. At 96 hours (fourth day), the selectivity cages were disassembled, and the cards were collected, labeled by date and treatment, and placed in plastic bags for evaluation.

Statistical analysis. The longevity and parasitism of the parental and F1 generations, as well as the emergence rate and sex ratio of the F1 and F2 generations, were evaluated. The toxicity of the EOs was classified according to the reduction in parasitism by parental and F1

females and emergence rate in F1 and F2 individuals: 1 = harmless (<30%), 2 = slightly harmful (30–79%), 3 = moderately harmful (80–99%), 4 = harmful (>99%), as recommended by IOBC (Sterk et al. 1999). Reductions in parasitism and emergence were calculated using the equation: % de reduction= 100 - mean [(% treatment/%control) × 100] (Carvalho et al. 2010). Data were first tested for normality using the Shapiro–Wilk test ($p > 0.05$). As all assumptions of normality and homoscedasticity were met, data were subjected to analysis of variance (ANOVA), and treatment means were compared using Tukey's test ($p<0.05$). (Sampaio 2002). When the data did not meet normality assumptions, the Kruskal-Wallis test was performed.

Results and Discussion

Sublethal effects of essential oils on the biological characteristics of *T. remus* reared on *S. frugiperda*. In the evaluation of *T. remus* parasitism on treated *S. frugiperda* eggs, the EOs of *B. dracunculifolia*, *C. citratus*, and *S. aromaticum* were classified as harmful (class 4). Similar effects were reported by Giraldi et al. (2025), that showed that *Baccharis* spp. EOs display a repellent effect on *T. remus* adults, thereby reducing the parasitism capacity of *S. frugiperda* eggs. Bomfim et al. (2025) found that *Trichogramma pretiosum* Riley, 1879 (Hymenoptera: Trichogrammatidae) adults were affected by volatiles in *C. citratus*. Moreover, Brügger et al. (2019) have shown that *C. citratus* EO has negative effects on the predator *Podisus nigrispinus* (Dallas, 1851) (Hemiptera: Pentatomidae) through topical application. The treatment with *C. viminalis* was classified as slightly harmful (class 2), with a 30.93% reduction in parasitism. Treatments with *C. verbenacea* and *S. terebinthifolius* were classified as innocuous (class 1), resulting in parasitism reduction of 16.42% and 25.30%, respectively. The highest parasitism rate was observed in the control treatment, with 86.04% of eggs parasitized (Tab. 1).

In the evaluation of *T. remus* longevity when exposed to eggs treated with EOs, no treatment showed statistical differences compared to the control (Tab. 1). The longevity ranged from 27.8 to 41.56 days, but there was no statistical difference.

When evaluating parasitism of untreated *S. frugiperda* eggs, there was no statistical difference among treatments. All treatments showed parasitism rates above 50% and were classified as innocuous (class 1) (Tab. 2).

In the longevity of F1 generation individuals of *T. remus*, emerging from *S. frugiperda* eggs treated with EOs, the treatment with *S. terebinthifolius* was the only one that differed statistically from the others, showing the lowest longevity (21.83 days) (Tab. 2).

In the emergence rate parameter of F1 generation individuals, only the treatment with *B. dracunculifolia* EO differed statistically from the others, presenting the lowest emergence rate, as parasitism occurred in only three replicates, and it was classified as harmful (class 4). Treatments with *C. viminalis*, *S. terebinthifolius*, and *C. verbenacea* were classified as innocuous (class 1), showing emergence reductions of 0%, 1.94%, and 18.96%, respectively (Tab. 3).

Regarding the F2 generation emergence rate, all treatments were classified as innocuous (class 1) and showed emergence rates above 80%, with no statistical differences between them (Tab. 3).

Regarding the sex ratio of F1 individuals, only the treatment with *B. dracunculifolia* EO differed statistically from the others, since parasitoid emergence occurred in only one replicate. There was no statistical difference among treatments in F2 sex ratio (Tab. 4).

Sublethal effects of essential oils on the biological characteristics of *T. remus* reared on *C. cephalonica*. As happened with *T. remus* reared on *S. frugiperda*, the EOs of *B. dracunculifolia*, *C. citratus*, and *S. aromaticum* were classified as harmful (class 4) to *T. remus* reared on *C. cephalonica*, with no parasitism observed and larval hatching occurring. With the exception of *C. viminalis* (class 1), all treatments differed from the control (Tab. 5).

Regarding the parental generation longevity, all treatments differed from the control, which showed the longest lifespan (5.53 days). The shortest longevity occurred with *C. citratus* EO, averaging 1 day (Tab. 5). The longevity of parasitoids reared on the alternative host *C. cephalonica* was very low, as also observed by Queiroz et al. (2017b), when compared to the parental generation reared on the natural host *S. frugiperda*. All treatments were innocuous (class 1) to the F1 parasitism.

The EOs of *C. citratus, B. dracunculifolia*, and *S. aromaticum* were highly detrimental to the parasitoid, causing a 100% reduction in parasitism in the parental generation for both hosts. None of the

Table 1. Parasitism and longevity (mean ± standard error) *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) parental generation exposed to treated eggs of *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae).

Treatment	Parasitism (%)†	PR (%)	IOBC class	Longevity (days)†
Control	80.58±5.67 a	---	---	33.44±3.47
C. verbenacea	63.20±7.56 ab	16.42	1	35.00±2.99
S. terebinthifolius	60.17±7.48 ab	25.30	1	37.56±1.61
C. viminalis	52.36±6.91 b	30.93	2	35.28±2.40
B. dracunculifolia	7.24±4.83 c	100	4	41.56±1.89
C. citratus	0.00±0.00 c	100	4	37.56±3.28
S. aromaticum	0.00±0.00 c	100	4	27.78±4.99
p-value	**<0.001***			0.593ns
H	89.36			4.62
df	6			6

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test ($p<0.05$). Means without letters do not differ statistically ($p\leq0.05$). PR = Parasitism reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Table 2. Parasitism and longevity (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) F1 generation.

Treatment	Parasitism (%)§	PR(%)	IOBC class	Longevity (days) †
Control	59.53±3.70	---	1	29.33±1.08 a
C. verbenacea	60.82±6.61	0	1	30.67±1.09 a
S. terebinthifolius	55.07±6.68	7.49	1	21.83±2.00 b
C. viminalis	66.21±5.20	0	1	28.17±1.12 a
B. dracunculifolia	54.52±2.73	8.41	1	29.39±1.92 a
p-value	**0.509ns**		p-value	0.0021*
F	0.83		H	16.51
df	89		df	4

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test ($p<0.05$). Means followed by the same letter in a column do not differ significantly according to Tukey's test ($p<0.05$). Means without letters do not differ statistically ($p\leq0.05$). PR = Parasitism reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

treatments showed sublethal effects on F1 parasitism (Tab. 6). The emergence rate of F1 *T. remus* individuals reared on *C. cephalonica* from eggs treated with *C. verbenacea* and *S. terebinthifolius* were lower than those of F1 individuals reared on *S. frugiperda*, due to the low parasitism rates in these treatments (Tab. 7). Regarding the emergence rate of F2 individuals, only the treatment with *C. verbenacea* was statistically different from the control, but all treatments showed emergence rates above 90% (Tab. 7). Only the treatment with *S. terebinthifolius* was statistically different from the control in the sex ratio of F1 individuals. No differences were observed in the sex ratio of F2 individuals (Tab. 8).

Table 3. Emergence rate (%) of F1 (mean ± standard error) and F2 (mean ± standard error) *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) generations.

Treatment	Emergence rate					
	F1 †	ER (%)	IOBC class	F2 †	ER (%)	IOBC class
Control	80.58±5.67 a	---	---	95.55±1.55	---	---
C. verbenacea	59.71±8.28 a	18.96	1	81.93±5.40	14.25	1
S. terebinthifolius	77.24±5.83 a	1.94	1	84.12±7.35	11.96	1
C. viminalis	78.72±7.47 a	0	1	92.65±2.28	3.03	1
B. dracunculifolia	5.56±5.56 b	100	4	95.43±1.27	0.12	1
p-value	<0.001*			0.069ns		
H	34.66			8.45		
Df	4			4		

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). Means without letters do not differ statistically (p≤0.05). ER = Emergence reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Table 4. Sex ratio (%) (mean ± standard error) of F1 and F2 *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) generations.

Treatment	Sex ratio	
	F1 †	F2 †
Control	0.66±0.06 a	0.86±0.01
C. verbenacea	0.78±0.03 a	0.77±0.05
S. terebinthifolius	0.80±0.02 a	0.75±0.06
C. viminalis	0.72±0.05 a	0.84±0.01
B. dracunculifolia	0.05±0.05 b	0.84±0.02
p-value	**<0.001***	0.437ns
H	29.30	3.78
df	4	4

† Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). Means without letters do not differ statistically (p≤0.05).

Table 5. Parasitism (%) and longevity (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) parental generation exposed to treated eggs of *Corcyra cephalonica* (Stainton, 1866) (Lepidoptera: Pyralidae).

Treatment	Parasitism (%)†	PR (%)	IOBC class	Longevity (days) ‡
Control	67.00±5.12 a	---	---	5.53±0.62 a
C. verbenacea	18.28±7.27 b	72.72	2	3.07±0.33 bc
S. terebinthifolius	17.47±6.74 b	73.93	2	2.87±0.13 bc
C. viminalis	63.91±3.06 a	4.61	1	4.00±0.29 b
B. dracunculifolia	0.00±0.00 b	100	4	2.87±0.40 bc
C. citratus	0.00±0.00 b	100	4	1.00±0.00 d
S. aromaticum	0.00±0.00 b	100	4	2.07±0.30 cd
p-value	**<0.001***		p-value	<0.001*
H	59.65		F	17.97
df	6		df	104

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). ‡ Means followed by the same letter in a column do not differ significantly according to Tukey's test (p<0.05). PR = Parasitism reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Table 6. Parasitism and longevity (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) F1 generation.

Treatment	Parasitism †	PR (%)	IOBC class	Longevity (days) §
Control	88.59±1.64 ab	---	---	12.60±0.95
C. verbenacea	73.92±5.18 a	16.56	1	11.20±0.98
S. terebinthifolius	90.65±2.74 b	0	1	9.80±0.76
C. viminalis	83.32±2.82 a	5.95	1	10.00±1.30
p-value	**0.0073***		p-value	0.195ns
H	12.01		F	1.62
df	3		df	59

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). § Means followed by the same letter in a column do not differ significantly according to Tukey's test (p<0.05). Means without letters do not differ statistically (p≤0.05). PR = Parasitism reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Limited effects were observed on F1 and F2 emergence and sex ratio for both hosts, suggesting that the primary impact of the harmful EOs occurs during direct exposure of the parental generation. Similar patterns of stronger parental effects with limited transgenerational persistence have been reported for botanical insecticides affecting egg parasitoids (Santana et al. 2025).

Selectivity to *Telenomus remus* adults reared on *S. frugiperda* and *C. cephalonica* eggs. Regarding the evaluation of *T. remus* parasitism, reared on *S. frugiperda* and exposed to EOs during the adult stage, only the treatment with *B. dracunculifolia* EO was statistically different from the control, showing the lowest mean parasitism rate of 18.52%, classified as slightly harmful (class 2). For the emergence rate, treatments with *B. dracunculifolia* and *S. aromaticum* differed statistically from the control, with 41.21% and 19.47%, respectively, both also classified as slightly harmful (Tab. 9).

When evaluating parasitism by *T. remus* reared on *C. cephalonica* and exposed to EOs during the adult stage, treatments with *S. terebinthifolius*, *B. dracunculifolia*, *C. verbenacea*, and *S. aromaticum* differed statistically from the control. Except for *C. viminalis*, all EOs were classified as slightly harmful (class 2). Regarding the emergence rate, all treatments were statistically similar to each other and were classified as innocuous (class 1) (Tab. 10).

Chaaban et al. (2018) also demonstrated the insecticidal activity of *B. dracunculifolia* EO on *Cochliomyia macellaria* (Fabricius, 1775) (Diptera: Calliphoridae), causing up to 70% larval mortality and up to 100% inhibition of adult emergence. In another study, Alves et al. (2018) reported that *B. dracunculifolia* EO has larvicidal activity (LC_{50} = 34.45 mg/L) against *Culex quinquefasciatus* Say, 1823 (Diptera: Culicidae). Şen & Gençer (2023) found that *S. aromaticum* EO has a highly toxic effect on the predators *Orius laevigatus* (Fieber, 1860) (Hemiptera: Anthocoridae) and *Nesidiocoris tenuis* (Reuter, 1895) (Hemiptera: Miridae), causing 100% and 80% mortality, respectively, at a 0.5% v/v dose.

Selectivity to *T. remus* pupae reared on *S. frugiperda* and *C. cephalonica* eggs. Parasitism by individuals exposed to the EOs during the pupal stage in *S. frugiperda* (Tab. 11) and *C. cephalonica* (Tab. 12)

Table 7. Emergence rate (%) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) F1 and F2 generations (mean ± standard error).

Emergence rate						
Treatment	**F1 †**	**ER (%)**	**IOBC class**	**F2 §**	**ER (%)**	**IOBC class**
Control	97.14±1.71 a	---	---	97.45±1.55 a	---	---
C. verbenacea	36.19±12.38 b	63.81	2	90.23±2.68 b	7.41	1
S. terebinthifolius	29.52±11.29 b	70.48	2	94.90±2.66 ab	2.62	1
C. viminalis	98.65±0.74 a	0	1	90.98±3.27 ab	6.64	1
p-value	**<0.0001***		p-value	0.046*		
H	21.51		F	2.84		
df	3		df	59		

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). § Means followed by the same letter in a column do not differ significantly according to Tukey's test (p<0.05). ER = Emergence reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Table 8. Sex ratio (%) (mean ± standard error) of F1 and F2 *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) generations.

Sex ratio		
Treatment	**F1 †**	**F2 †**
Control	0.55±0.06 ab	0.83±0.02
C. verbenacea	0.46±0.07 bc	0.82±0.04
S. terebinthifolius	0.43±0.07 c	0.87±0.01
C. viminalis	0.78±0.03 a	0.80±0.03
p-value	**0.0009***	**0.463ns**
H	**16.32**	**2.55**
df	**3**	**3**

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). Means without letters do not differ statistically (p≤0.05).

Table 9. Parasitism viability and emergence (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) reared on *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) when exposed to treatments during the adult stage.

Treatment	Parasitism (%)§	PR (%)	IOBC class	Emergence rate (%)†	ER (%)	IOBC class
Control	78.62±5.40 a	---	---	94.29±2.57 a	---	---
C. verbenacea	70.93±4.23 a	9.78	1	84.73±8.44 a	10.14	1
S. terebinthifolius	65.61±5.43 a	16.55	1	87.53±2.82 ab	7.17	1
C. viminalis	64.80±8.04 a	17.58	1	89.27±3.61 a	5.32	1
B. dracunculifolia	18.52±3.33 b	76.44	2	41.21±6.20 bc	56.29	2
C. citratus	68.71±6.49 a	12.60	1	76.13±7.87 ab	19.26	1
S. aromaticum	56.35±7.74 a	28.33	1	19.47±4.97 c	79.35	2
p-value	**<0.001***		p-value	<0.001*		
F	10.53		H	24.19		
df	34		df	6		

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). § Means ±SE within columns followed by the same letter are not significantly different based on Tukey test (p<0.05). PR = Parasitism reduction compared to control treatment. ER = Emergence reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

was impaired, and all EOs were classified as slightly harmful (class 2). This result can be explained by Parreira et al. (2017), who sprayed EOs from three species, including *S. aromaticum*, on *Ephestia kuehniella* Zeller, 1879 (Lepidoptera: Pyralidae) eggs parasitized by *T. pretiosum* (a parasitoid in the egg-larva, pre-pupal, and pupal stages), where the greatest reduction in emergence occurred during the pupal stage. Other authors reported that *C. citratus* had a slightly harmful effect on *T. pretiosum* when the plant extract was pulverized to its pupae (Glaudenucci et al. 2020).

For the emergence rate parameter, all EOs were classified as harmless for both hosts, except for *S. terebinthifolius* oil, which was considered slightly harmful to individuals reared on *S. frugiperda*.

Table 10. Parasitism viability and emergence (%) (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) reared on *Corcyra cephalonica* (Stainton, 1866) (Lepidoptera: Pyralidae) when exposed to treatments during the adult stage.

Treatment	Parasitism (%)§	PR (%)	IOBC class	Emergence rate (%)§	ER (%)	IOBC class
Control	87.66±1.26 a	---	---	99.90±0.10	---	---
C. verbenacea	42.99±5.17 b	50.96	2	88.17±7.33	11.74	1
S. terebinthifolius	51.12±7.12 b	41.68	2	95.73±1.76	4.17	1
C. viminalis	66.68±6.07 ab	23.93	1	79.66±6.53	20.26	1
B. dracunculifolia	46.26±8.23 b	47.23	2	91.04±4.84	8.87	1
C. citratus	60.28±11.43 ab	31.23	2	91.98±4.87	7.93	1
S. aromaticum	39.31±8.08 b	55.16	2	86.30±5.62	13.61	1
p-value	**0.001***			0.051ns		
F	5.23			2.43		
df	34			34		

§ Means ±SE within columns followed by the same letter are not significantly different based on Tukey test (p<0.05). Means without letters do not differ statistically (p≤0.05). PR = Parasitism reduction compared to control treatment. ER = Emergence reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Table 11. Parasitism viability and emergence (%) (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) when exposed to treatments during the pupal stage in *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae).

Treatment	Parasitism (%)§	PR (%)	IOBC class	Emergence rate (%)§	ER (%)	IOBC class
Control	68.78±4.33	---	---	99.59±0.30 a	---	---
C. verbenacea	37.64±4.98	45.27	2	88.51±5.23 ab	11.13	1
S. terebinthifolius	29.50±10.44	57.11	2	64.37±7.62 b	35.37	2
C. viminalis	47.64±9.07	30.74	2	76.37±5.47 ab	23.32	1
B. dracunculifolia	37.31±5.69	45.75	2	94.93±2.69 ab	4.68	1
C. citratus	45.79±9.38	33.43	2	92.51±2.23 ab	7.11	1
S. aromaticum	37.76±7.31	45.10	2	87.48±1.88 ab	12.16	1
p-value	**0.058ns**			0.027*		
F	2.35			2.84		
df	34			34		

§ Means ±SE within columns followed by the same letter are not significantly different based on Tukey test (p<0.05). Means without letters do not differ statistically (p≤0.05). PR = Parasitism reduction compared to control treatment. ER = Emergence reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Table 12. Parasitism viability and emergence (%) (mean ± standard error) of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) when exposed to treatments during the pupal stage in *Corcyra cephalonica* (Stainton, 1866) (Lepidoptera: Pyralidae).

Treatment	Parasitism (%)†	PR (%)	IOBC class	Emergence rate (%)§	ER (%)	IOBC class
Control	61.92±4.01 a	---	---	97.69±2.76	---	---
C. verbenacea	20.69±2.92 bc	66.59	2	91.45±5.18	6.39	1
S. terebinthifolius	19.14±2.70 bc	69.09	2	79.90±18.82	18.21	1
C. viminalis	28.55±3.90 b	53.89	2	92.67±8.78	5.14	1
B. dracunculifolia	20.67±1.12 bc	66.62	2	89.25±8.82	8.64	1
C. citratus	18.91±2.48 bc	69.46	2	85.51±9.90	12.47	1
S. aromaticum	12.63±3.17 c	79.60	2	89.37±9.88	8.52	1
p-value	**0.003***		p-value	0.137ns		
H	19.93		F	1.79		
df	6		df	34		

†Means followed by different letters in the column differ significantly according to the Kruskal-Wallis test (p<0.05). § Means ±SE within columns followed by the same letter are not significantly different based on Tukey test (p<0.05). Means without letters do not differ statistically (p≤0.05). PR = Parasitism reduction compared to control treatment. ER = Emergence reduction compared to control treatment. IOBC/WPRS classes: 1 = innocuous (<30%), 2 = slightly harmful (30-79%), 3 moderately harmful = (80-99%), 4 = harmful (>99%).

Conclusion

The EOs evaluated showed different levels of selectivity toward *T. remus*, depending on the parasitoid developmental stage and host species. *Baccharis dracunculifolia*, *C. citratus*, and *S. aromaticum* significantly reduced the parental generation parasitism, reared on both *S. frugiperda* and *C. cephalonica*. However, limited effects were observed on F1 and F2 generations, indicating that the main impact occurs during direct exposure of adults. *Schinus terebinthifolius*, *C. verbenacea*, and *C. viminalis* EOs showed greater selectivity to the parasitoid. In addition, parasitoids reared on *C. cephalonica* showed reduced longevity compared with those reared on *S. frugiperda*. Overall, the results suggest that some EOs may be compatible with *T. remus* and could be integrated into *S. frugiperda* management programs; however, further studies under semi-field and field conditions are necessary, and their use should comply with ecological selectivity guidelines to ensure the preservation of biological control agents.

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Authors' Contributions

MOM: Conceptualization, Investigation, Methodology, Formal Analysis, Data Curation, Writing - original draft, Writing - review and editing; JPAB: Conceptualization, Investigation, Methodology, Formal Analysis, Data Curation, Writing - original draft; RCO: Project administration, Supervision, Validation, Writing - review and editing.

Conflict of Interest Statement

The authors declare that they have no conflict of interest

References

Alves, K. F.; Caetano, F. H.; Pereira Garcia, I. J.; Santos, H. L.; Silva, D. B.; Siqueira, J. M.; Tanaka, A. S.; Alves, S. N. (2018) *Baccharis dracunculifolia* (Asteraceae) essential oil toxicity to *Culex quinquefasciatus* (Culicidae). *Environmental Science and Pollution Research,* 25(31): 31718–31726. doi: 10.1007/s11356-018-3149-x

Angon, P. B., Mondal, S., Jahan, I., Datto, M., Antu, U. B., Ayshi, F. J., Islam, M. S. (2023) Integrated pest management (IPM) in agriculture and its role in maintaining ecological balance and biodiversity. *Advances in Agriculture*, 2023: 5546373. doi: 10.1155/2023/5546373

Bernardi, E. B.; Haddad, M. D. L.; Parra, J. R. P. (2000) Comparison of artificial diets for rearing *Corcyra cephalonica* (Stainton, 1865) (Lep., Pyralidae) for *Trichogramma* mass production. *Revista Brasileira de Biologia*, 60(1): 45-52. doi: 10.1590/s0034-71082000000100007

Bomfim, J. P. A.; da Silva, N. N. P., da Silva, C. B.; Amaral, J. C.; das Graças Fernandes da Silva, M. F.; Bonfim, F. P. G.; de Oliveira, R. C. (2025) Compatibility of *Cymbopogon citratus* (DC.) Stapf (Poaceae) essential oil with egg parasitoids for the control of *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae). *Phytoparasitica*, 53(1): 2. doi: 10.1007/s12600-024-01223-w

Brügger, B. P.; Martínez, L. C.; Plata-Rueda, A.; Castro, B. M. D. C. E.; Soares, M. A.; Wilcken, C. F.; Carvalho, A. G.; Serrão, J. E.; Zanuncio, J. C. (2019) Bioactivity of the *Cymbopogon citratus* (Poaceae) essential oil and its terpenoid constituents on the predatory bug, *Podisus nigrispinus* (Heteroptera: Pentatomidae). *Scientific Reports*, 9(1): 8358. doi: 10.1038/s41598-019-44709-y

Carvalho, G. A.; Godoy, M. S.; Parreira, D. S.; Lasmar, O.; Souza, J. R.; Moscardini, V. F. (2010) Selectivity of growth regulators and neonicotinoids for adults of *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae). *Revista Colombiana de Entomologia*, 36(2): 195-201. 10.25100/socolen.v36i2.9144

Chaaban, A.; Martins, C. E. N.; Bretanha, L. C.; Micke, G. A.; Carrer, A. R.; Rosa, N. F.; Ferreira, L.; Molento, M. B. (2018) Insecticide activity of *Baccharis dracunculifolia* essential oil against *Cochliomyia macellaria* (Diptera: Calliphoridae). *Natural Product Research*, 32(24): 2954-2958. doi: 10.1080/14786419.2017.1392947

Cruz, G. S.; Wanderley-Teixeira, V.; Oliveira, J. V.; Correia, A. A.; Breda, M. O.; Alves, T. J. S.; Cunha, F. M.; Teixeira, A. A. C.; Dutra, K. A.; Navarro, D. M. A. F. (2014) Bioactivity of *Piper hispidinervum* (Piperales: Piperaceae) and *Syzygium aromaticum* (Myrtales: Myrtaceae) oils, with or without formulated Bta on the biology and immunology of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Journal of Economic Entomology*, 107(1): 144-153. doi: 10.1603/ec13351

Fortes, A. D. R.; Coelho Jr, A.; Amorim, D. J.; Demetrio, C. G.; Parra, J. R. (2023) Biology and quality assessment of *Telenomus remus* (Hymenoptera: Scelionidae) and *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) in eggs of *Spodoptera* spp. for augmentative biological control programs. *Journal of Insect Science*, 23(5): 5. doi: 10.1093/jisesa/iead047

Giraldi, G. T.; Zimmermann, R. C.; do Amaral, W.; Martins, C. E. N.; Schafaschek, A. M.; Maia, B. H. L. N.; dos Santos, E. F.; Mazarotto, E. J.; da Silva, M. A. N.; Foester, L. A. (2025) Toxicity of essential oils from Baccharis species on *Spodoptera frugiperda* and their selectivity to the parasitoid *Telenomus remus*. *Journal of Pest Science*, 98: 2247–2263. doi: 10.1007/s10340-025-01936-9

Glaudenucci, J.; Marasca, I.; Pernambuco Filho, J. C. A.; Bonfim, F. P. G.; Bueno, R. C. O. F. (2020) Selectivity and sublethal effects of botanical extracts to pupae of *Trichogramma pretiosum* Riley, 1879 (Hymenoptera: Trichogrammatidae). *Journal of Experimental Agriculture International,* 42(9): 136–146. doi: 10.9734/JEAI/2020/v42i930594

Greene, G. L.; Leppla, N. C.; Dickerson, W. A. (1976) Velvetbean caterpillar: a rearing procedure and artificial medium. *Journal of Economic Entomology*, 69(4): 487-488. doi: 10.1093/jee/69.4.487

Guerra, I. C. D.; de Oliveira, P. D. L.; de Souza Pontes, A. L.; Lúcio, A. S. S. C.; Tavares, J. F.; Barbosa-Filho, J. M.; Madruga, M. S.; de Souza, E. L. (2015) Coatings comprising chitosan and *Mentha piperita* L. or *Mentha villosa* Huds essential oils to prevent common postharvest mold infections and maintain the quality of cherry tomato fruit. *International Journal of Food Microbiology*, 214: 168-178. doi: 10.1016/j.ijfoodmicro.2015.08.009

Hassan, E.; Obaidoon, Y.; Mostafiz, M. M.; Senior, L. (2023) Effect of plant essential oil formulations on *Bemisia Tabaci* MEAM1 (Gennadius) and its parasitoid *Eretmocerus hayati* (Zolnerowich and Rose). *Plants*, 12(24): 4137. doi: 10.3390/plants12244137

Hassan, S. A.; Halsall, N.; Gray, A. P.; Kuehner, C.; Moll, M.; Bakker, F. M.; Roembke, J.; Yousef, A.; Nasr, F.; Abdelgader, H. A. (2000) A laboratory method to evaluate the side effects of plant protection products on *Trichogramma cacoeciae* Marchal (Hymenoptera: Trichogrammatidae). In: Candolfi, M. P.; Blümel, S.; Forster, R.; Bakker, F. M.; Grimm, C.; Hassan, S. A.; Heimbach, U.; Mead-Briggs, M.A.; Reber, B.; Schmuck, R.; Vogt, H. (Eds), *Guidelines to evaluate side-effects of plant protection products to non-target arthropods*, pp. 107-119. Reinheim: IOBC/WPRS.

Knaak, N.; Wiest, S. L.; Andreis, T. F.; Fiuza, L. M. (2013) Toxicity of essential oils to the larvae of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Journal of Biopesticides*, 6(1): 49.

Li, T. H.; de Freitas Bueno, A.; Desneux, N.; Zhang, L.; Wang, Z.; Dong, H.; Wang, S.; Zang, L. S. (2023) Current status of the biological control of the fall armyworm *Spodoptera frugiperda* by egg parasitoids. *Journal of Pest Science*, 96(4): 1345-1363. doi: 10.1007/s10340-023-01639-z

Lisi, F.; Siscaro, G.; Biondi, A.; Zappalà, L.; Ricupero, M. (2025) Non-target effects of bioinsecticides on natural enemies of arthropod pests. *Current Opinion in Environmental Science & Health*, 45: 100624. doi: 10.1016/j.coesh.2025.100624

Parra, J. R. P. (2019) Controle biológico na agricultura brasileira. *Entomological Communications*, 1: ec01002. doi: 10.37486/2675-1305.ec01002

Parreira, D. S.; Alcántara-de la Cruz, R.; Leite, G. L. D.; de Souza Ramalho, F.; Zanuncio, J. C.; Serrão, J. E. (2018b) Quantifying the harmful potential of ten essential oils on immature *Trichogramma pretiosum* stages. *Chemosphere*, 199: 670-675. doi: 10.1016/j.chemosphere.2018.02.083

Parreira, D. S.; Alcántara-de la Cruz, R.; Zanuncio, J. C.; Lemes, P. G.; da Silva Rolim, G.; Barbosa, L. R.; Leite, G. L. D.; Serrão, J. E. (2018a) Essential oils cause detrimental effects on biological parameters of *Trichogramma galloi* immatures. *Journal of Pest Science*, 91(2): 887-895. doi: 10.1007/s10340-017-0945-x

Parreira, D. S.; Dimaté, F. A. R.; Batista, L. D.; Ribeiro, H. C. B.; Guanabens, R. E.; da Cunha, A. F.; Ribeiro, R. C. (2017) Efeito de óleos essenciais sobre estágios imaturos de *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae). *Ensaios e Ciência: Ciências Biológicas, Agrárias e da Saúde*, 21(2): 80-85. doi: 10.17921/1415-6938.2017v21n2p80-85

Pomari-Fernandes, A.; Bueno, A. F.; Queiroz, A. P.; De Bortoli, S. A. (2015) Biological parameters and parasitism capacity of *Telenomus remus* Nixon (Hymenoptera: Platygastridae) reared on natural and factitious hosts for successive generations. *African Journal of Agricultural Research*, 10(33): 3225-3233. doi: 10.5897/AJAR2015.10154

Pratissoli, D.; Bueno, R. C. O. F.; Carvalho, J. R. (2019) O controle biológico. In: Pratissoli, D.; Bueno, R. C. O. F.; Carvalho, J.R. (Eds.), *Trichogramma: da coleta à pesquisa aplicada*, pp. 15-17. Alegre: Unicopy.

Priyanka, S. L.; Jeyarani, S.; Sathiah, N.; Mohankumar, S.; Nakkeeran, S. (2023) Influence of host egg age on parasitic potential of the entomophagous, *Telenomus remus* Nixon (Hymenoptera: Scelionidae) against the Fall armyworm, *Spodoptera frugiperda* (JE Smith)(Lepidoptera: Noctuidae) and investigations on the developmental biology and ultrastructure of egg parasitoid immature stages. *Egyptian Journal of Biological Pest Control*, 33(1): 26. doi: 10.1186/s41938-023-00676-1

Queiroz, A. P.; de Freitas Bueno, A.; Pomari-Fernandes, A.; Grande, M. L. M.; Bortolotto, O. C.; da Silva, D. M. (2017a) Quality control of *Telenomus remus* (Hymenoptera: Platygastridae) reared on the factitious host *Corcyra cephalonica* (Lepidoptera: Pyralidae) for successive generations. *Bulletin of Entomological Research*, 107(6): 791-798. doi: 10.1017/S000748531700030X

Queiroz, A. P.; Bueno, A. D. F.; Pomari-Fernandes, A.; Grande, M. L. M.; Bortolotto, O. C.; Silva, D. M. (2017b) Low temperature storage of *Telenomus remus* (Nixon) (Hymenoptera: Platygastridae) and its factitious host *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae). *Neotropical Entomology*, 46(2): 182-192. doi: 10.1007/s13744-016-0442-6

Sampaio, I. B. M. (2002) *Estatística aplicada à experimentação animal*. 2ª. ed. Belo Horizonte: Fundação de Estudo e Pesquisa em Medicina Veterinária e Zootecnia.

Santana, E. D. R.; Thiesen, L. V.; Ribeiro, L. D. P.; Takahashi, T. A.; Parra, J. R. P.; Yamamoto, P. T. (2025) Harmful to Parents, Harmless to Offspring: Lethal and Transgenerational Effects of Botanical and Synthetic Insecticides on the Egg Parasitoid *Trichogramma atopovirilia*. *Insects*, 16(5): 493. doi: 10.3390/insects16050493

Şen, E.; Gençer, N. (2023) Effects of five essential oils on three generalist predators and two important whitefly parasitoids. *Zemdirbyste*, 110(3): 279-286. doi: 10.13080/z-a.2023.110.032

Sterk, G.; Hassan, S. A.; Baillod, M.; Bakker, F.; Bigler, F.; Blümel, S.; Bogenschütz, H.; Boller, E.; Bromand, B.; Brun, J., et al. (1999) Results of the seventh joint pesticide testing programme carried out by the IOBC/WPRS-Working Group 'Pesticides and Beneficial Organisms'. *BioControl*, 44(1): 99-117. doi: 10.1023/A:1009959009802

Tagliari, M. S.; Knaak, N.; Fiuza, L. M. (2010) Efeito de extratos de plantas na mortalidade de lagartas de *Spodoptera frugiperda* (JE Smith)(Lepidoptera: Noctuidae). *Arquivos do Instituto Biológico*, 77(2): 259-264. doi: 10.1590/1808-1657v77p2592010

Tang, Y.; Zou, Q.; Yu, G.; Liu, F.; Wu, Y.; Zhao, X.; Wang, W.; Liu, X.; Hu, F.; Wang, Z. (2025) Immunotranscriptomic profiling of *Spodoptera frugiperda* challenged by different pathogenic microorganisms. *Insects*, 16(4): 360. doi: 10.3390/insects16040360

Tirelli, A. A.; Alves, D. S.; Carvalho, G. A.; Sâmia, R. R.; Brum, S. S.; Guerreiro, M. C. (2010) Efeito de frações tânicas sobre parâmetros biológicos e nutricionais de *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Ciência e Agrotecnologia*, 34(6): 1417-1424. doi: 10.1590/s1413-70542010000600009

Zanuncio, J. C.; Mourão, S. A.; Martínez, L. C.; Wilcken, C. F.; Ramalho, F. S.; Plata-Rueda, A.; Soares, M. A.; Serrão, J. E. (2016) Toxic effects of the neem oil (*Azadirachta indica*) formulation on the stink bug predator, *Podisus nigrispinus* (Heteroptera: Pentatomidae). *Scientific Reports*, 6(1): 30261. doi: 10.1038/srep30261