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Marylia Posser Cargnin, Daniela Neves Godoy, Ramon Braidá Palharini, Luiz Francisco Warpechowski, Venicius Ernesto Pretto, Eduardo Argenta Steinhaus, Oderlei Bernardi

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Laboratory and greenhouse evaluation of insecticides for the control of *Crociosema* sp. (Lepidoptera: Tortricidae) in soybean

Marylia Posser Cargnin¹ (<https://orcid.org/0000-0003-1980-6816>)
Daniela Neves Godoy¹ (<https://orcid.org/0000-0003-2849-8886>)
Ramon Braidá Palharini¹ (<https://orcid.org/0000-0003-4620-3762>)
Luiz Francisco Warpechowski¹ (<https://orcid.org/0009-0006-4748-5406>)
Venicius Ernesto Pretto¹ (<https://orcid.org/0000-0002-9201-0163>)
Eduardo Argenta Steinhaus¹ (<https://orcid.org/0000-0002-3608-4598>)
Oderlei Bernardi^{*} (<https://orcid.org/0000-0001-9320-1642>)

¹Departamento de Defesa Fitossanitária, Centro de Ciências Rurais (CCR), Universidade Federal de Santa Maria (UFSM), 97105-900, Santa Maria, RS, Brasil. E-mail: oderlei.bernardi@ufsm.br. *Corresponding author.

ABSTRACT: The Neotropical bud borer, *Crociosema aporema* (Walsingham 1914) (Lepidoptera: Tortricidae), is a secondary pest of soybean in Brazil. Outbreaks have become more frequent in soybean fields following the development of practical resistance to Cry1Ac-expressing soybean derived from *Bacillus thuringiensis* Berliner (*Bt*). Recent molecular and morphological studies suggested that the species responsible for these outbreaks differ from *C. aporema* and may represent an undescribed species within the genus *Crociosema*. Due to the resistance of *Crociosema* sp. to Cry1Ac soybean and the increased use of insecticides, we conducted laboratory (diet-overlay and leaf bioassays) and greenhouse (artificial infestation) evaluations of selected insecticides against *Crociosema* sp. In diet-overlay assays, L2 larvae were more susceptible to spinetoram, chlorantraniliprole, chlorfenapyr, indoxacarb, and thiodicarb than to flubendiamide and triflumuron. In accordance with diet-overlay results, insecticides with higher lethality achieved greater control in leaf bioassays (>77% control at 6 days after field-dose application) and greenhouse trials (>96% control). In contrast, flubendiamide- and triflumuron-based products were consistently less effective (<66% control) across both assay types. These findings provided practical guidance for optimizing chemical control of *Crociosema* sp. in soybean production systems in Brazil and other South American countries.

Key words: bud borer, chemical control, *Bt* soybean, integrated pest management.

Avaliação em laboratório e casa de vegetação de inseticidas para controle de *Crociosema* sp. (Lepidoptera: Tortricidae) em soja

RESUMO: A broca-das-axilas, *Crociosema aporema* (Walsingham, 1914) (Lepidoptera: Tortricidae), é considerada praga secundária da soja no Brasil. Contudo, surtos populacionais tornaram-se mais frequentes em soja após a evolução de resistência prática à soja que expressa Cry1Ac de *Bacillus thuringiensis* Berliner (*Bt*). Evidências moleculares e morfológicas recentes indicam que a espécie associada a esses surtos difere de *C. aporema*, podendo representar uma espécie ainda não descrita do gênero *Crociosema*. Neste sentido, esta pesquisa teve o intuito de avaliar a eficácia de inseticidas em bioensaios laboratoriais (aplicação na superfície da dieta artificial e em folhas de soja) e experimentos em casa de vegetação (infestação artificial) no controle de *Crociosema* sp. Os resultados revelam que nos bioensaios em dieta artificial, larvas de segundo instar (L2) foram mais suscetíveis a spinetoram, clorantraniliprole, clorfenapir, indoxacarbe e tiodicarbe do que a flubendiamida e triflumuron. De acordo com resultados prévios, os inseticidas com maior letalidade tiveram maior controle em bioensaios com folhas de soja (controle >77% aos 6 dias após a aplicação da dose de campo) e em casa de vegetação (controle >96%). Em contraste, flubendiamida e triflumuron apresentaram menor controle (<66%) em laboratório e em casa de vegetação. Esses resultados fornecem informações práticas para a otimização do controle químico de *Crociosema* sp. em soja no Brasil e em outros países da América do Sul.

Palavras-chave: broca-das-axilas, controle químico, soja *Bt*, manejo integrado de pragas.

1 INTRODUCTION

2
3 The soybean bud borer, *Crociosema*
4 *aporema* (Walsingham 1914) (Lepidoptera:
5 Tortricidae), is an oligophagous pest of Fabaceae
6 and the main bud borer species infesting soybean
7 [*Glycine max* (L.) Merrill] in Brazil (FERREIRA,
8 1980; PANIZZI, 2013; HORIKOSHI et al., 2021a).
9 This species was also reported infesting soybean
10 in Argentina, Uruguay, Chile, Colombia, Costa
11 Rica, and Peru (PEREYRA & SÁNCHEZ, 1997;
12 LILJESTHRÖM & ROJAS-FAJARDO, 2005;
13 ALTESOR et al., 2010). In addition to soybeans, *C.*

aporema also attacks peanuts (*Arachis hypogaea* L.),
alfalfa (*Medicago sativa* L.), beans (*Phaseolus vulgaris*
L.), white lupine (*Lupinus albus* L.), and white clover
(*Trifolium repens* L.) (BIEZANKO, 1961).

Damage by *C. aporema* can occur during
the vegetative and reproductive stages of soybean
(HAYASHIDA et al., 2023). Neonates initially feed
on soybean leaflets and buds, forming leafrolls around
the terminal and lateral buds (LILJESTHRÖM et
al., 2001). As the larvae grow, they create tunnels
in the stem because their feeding obstructs the
movement of sap, resulting in a high number of
secondary branches and reduction in plant growth

(SÁNCHEZ & PEREIRA, 2008; LILJESTHRÖM et al., 2001). However, larvae can also attack flowers and pods during the reproductive stages, causing flower bud and pod drop or damage to soybean seeds (FERREIRA, 1980; BENTANCOURT & SCATONI, 1989).

In Brazil, during the 2020/2021 soybean season, unexpected damage by an insect reported to be *C. aporema* was reported in soybean fields planted with cultivars expressing the Cry1Ac toxin from *Bacillus thuringiensis* Berliner (*Bt*) (HORIKOSHI et al., 2021b). Subsequent studies demonstrated that this species had evolved practical resistance to Cry1Ac soybean (STEINHAUS et al., 2025). However, a recent molecular study using DNA barcoding indicated that the bud borer species that infests soybean in Brazil is not *C. aporema*, but a different species from the genus *Crocidosema* Zeller that has not yet been described (FERNANDES et al., 2024).

Given the field-evolved resistance of *Crocidosema* sp. to Cry1Ac soybean and their recent demographic expansion in soybean in Brazil (HORIKOSHI et al., 2021b; FERNANDES et al., 2024), it is likely that the use of insecticides against this pest will increase during the next soybean seasons. However, there are no recent studies reporting the susceptibility of *Crocidosema* sp. to modern chemical insecticides recommended for controlling this species in soybeans. The last studies reporting control efficacy of insecticides against *Crocidosema* sp. were carried out during the 1970s and '80s with old insecticides that act on the nervous system, including products currently banned in Brazil (FOERSTER, 1978; FOERSTER & MATIOLI, 1986).

To address this knowledge gap, laboratory and greenhouse trials were conducted to evaluate the susceptibility of *Crocidosema* sp. to selected insecticides,

providing data to support integrated pest management (IPM) and insect resistance management (IRM).

MATERIALS AND METHODS

Insects

In this study, a single population of *Crocidosema* sp. resistant to the Cry1Ac toxin expressed in soybean was used. This population was collected from fields containing Cry1Ac soybean and selected for resistance to Cry1Ac toxin as described by STEINHAUS et al. (2025). After selection, this population has been reared under laboratory conditions using an artificial diet (Multiple Species, Southland-MS; Start BioScience Materiais para Laboratórios Ltda, Valinhos, Brazil) deposited in 128-well trays (Biosupply Comércio de Plásticos, Embalagens, Químicos e Suprimentos Ltda, São Paulo, Brazil) at a volume of 1 ml/well. Every three generations, neonates were exposed to selection pressure on Cry1Ac soybean leaves and the survivors after 5 days were transferred to the artificial diet to complete the biological cycle.

Insecticides

Insecticides evaluated for susceptibility of *Crocidosema* sp. are listed in table 1.

Diet-overlay bioassays

Diet-overlay bioassays were performed using 24-well acrylic plates (Costar, São Paulo, SP, Brazil), with each well received 1 ml of an artificial diet (Multiple Species, Southland-MS). After plate preparation, 6–8 concentrations of each insecticide, arranged on a logarithmic scale, were prepared in distilled water (Table 1). Triton X-100 (Sigma–Aldrich, São Paulo, SP, Brazil) was added

Table 1 - Selected insecticides used to characterize the susceptibility of *Crocidosema* sp.

Active ingredient (a.i.)	Trade name	A.I. (%)	Dose (g a.i./ha) ^a	Company/manufacturer
Spinetoram	Exalt	12	18	CTVA Proteção de Cultivos Ltda., Barueri, SP, Brazil
Chlorantraniliprole	Premio	20	30	FMC Química do Brasil Ltda, Campinas, SP, Brazil
Chlorfenapyr	Pirate	24	36	BASF S.A., São Paulo, SP, Brazil
Indoxacarb	Avatar	15	22.5	FMC Química do Brasil Ltda, Campinas, SP, Brazil
Thiodicarb	Larvin	80	120	Bayer S.A., São Paulo, SP, Brazil
Flubendiamide	Belt	48	72	Bayer S.A., São Paulo, SP, Brazil
Triflumuron	Certero	48	72	Bayer S.A., São Paulo, SP, Brazil

^aField dose used in soybean leaf bioassays and greenhouse trials.

to each solution at 0.1% (v/v) to ensure a uniform distribution over the diet surface. A 30 µl aliquot of each concentration was dispensed into the wells using an automatic replication pipette (Multipette E3x; Eppendorf, São Paulo, SP, Brazil), while control wells received distilled water with surfactant. After drying in a laminar flow cabinet, a single L2 larva (~0.3 cm long) was placed in each well. Plates were then closed and maintained in a climatic room at 25 ± 2 °C, $60 \pm 10\%$ relative humidity and 14-h:10-h (light:dark) photoperiod. The experiment followed a completely randomized design with two replicates of 20–24 larvae each, totalling 42–48 larvae/concentration. Larval mortality was recorded after 48 h (spinetoram, chlorfenapyr, indoxacarb and thiodicarb), 96 h (chlorantraniliprole and flubendiamide) or 120 h (triflumuron), in accordance with the mode of action of each insecticide as suggested by the Insecticide Resistance Action Committee (IRAC, 2025).

Leaf bioassays

Non-Bt soybean (BMX Valente RR 6968 RSF; Brasmax Genética, Passo Fundo, RS, Brazil) was cultivated under field conditions at a density of ten plants/m within rows and 0.45 m between rows. At the V_{4-5} growth stage, plants were treated with the field dose of insecticides (Table 1) at a simulated spray volume of 150 L/ha using a backpack sprayer equipped with a 2-m bar and 0.5-m nozzle spacing (XR 110.02 fan-type nozzle tips; TeeJet Technologies Co., Glendale Heights, IL, USA). After drying, fully expanded trifoliate leaves from the upper third of the plants were removed and individually placed on filter paper over a 2.5% agar–water gel mixture (3 ml/cup) in 100-ml plastic cups. Unsprayed leaves served as controls. Each cup was infested with two L2 larvae, covered with a lid, and maintained in a climatic room under the same environmental conditions described above. The experiment was arranged in a completely randomized design with 20 replicates of two larvae each, totalling 40 larvae/insecticide. Larval mortality was recorded at 4 and 6 days after exposure (DAE).

Greenhouse trials

Non-Bt soybean (BMX Valente RR 6968 RSF) was sown in 12-L plastic pots containing a 2:1 (v/v) mixture of soil and plant material, with ten seeds/pot. At the V_3 growth stage, six plants/pot were retained and treated with the field dose of insecticides (Table 1), as described above. After spraying, plants were confined in PVC cages (23 cm high × 10 cm diameter; two plants/cage) and each plant was artificially infested with three L2 larvae, totalling six

larvae/cage. Cages were covered with white voile-type fabric to prevent larval escape, while unsprayed plants served as controls. The trial was conducted using a completely randomized design with 18–20 replicate cages/insecticide, comprising a total of 108–120 larvae/insecticide. Larval mortality was recorded at 4 and 6 DAE.

Data analysis

The mortality data of L2 larvae of *Crociosema* sp. in diet-overlay assays was analyzed with a generalized linear model (GLM) assuming a binomial distribution and a probit link function. Model fit was evaluated with the *hnp* package using a simulated envelope and χ^2 test (MORAL et al., 2017); non-significant deviation between observed and expected χ^2 values ($P > 0.05$) indicate an adequate fit. Lethal concentrations (LC_{50} and LC_{90}) estimates, with 95% confidence intervals (CIs), were obtained with the *MASS* package. Pairwise comparisons of LC values were performed with the z-test, considering $P < 0.05$ (two-tailed) as significant (ROBERTSON et al., 2007). These analyses were conducted in R 4.3.1 (R CORE TEAM, 2021).

The percentage mortality values from leaf and greenhouse bioassays were corrected based on untreated controls using the Abbott's formula (ABBOTT, 1925). The Shapiro–Wilk and Bartlett tests (BARLETT, 1937; SHAPIRO & WILK, 1965) indicated that the mortality did not meet the assumptions of parametric distribution. Then, mortality data were arcsine square-root transformed prior to analysis, although untransformed means and standard errors are presented in the figures. Two-way ANOVA with insecticide and evaluation time (DAE) as main factors was conducted using PROC GLM procedure, and mean differences were calculated with the LSMEANS statement and Tukey–Kramer adjustment at $P < 0.05$. These analyses were performed in SAS 9.0 (SAS INSTITUTE, 2002).

RESULTS

Diet-overlay bioassays

The susceptibility of L2 larvae of *Crociosema* sp. to the tested insecticides differed significantly, as shown by pairwise z-tests ($P < 0.05$) (Table 2). Based on LC_{50} values, larvae were more susceptible to spinetoram, chlorantraniliprole, chlorfenapyr, indoxacarb and thiodicarb (≤ 0.17 a.i./cm² of diet) than to flubendiamide (0.58 µg a.i./cm² of diet) and triflumuron (4.29 µg a.i./cm² of diet). LC_{90} estimates also differed among insecticides;

Table 2 - Lethal-concentration response (LC; $\mu\text{g a.i./cm}^2$ of diet) of *Crociosema* sp. to selected insecticides.

Insecticide	n	Fit of probit lines			LC ₅₀ (95% CI) ^d	LC ₉₀ (95% CI) ^d
		Slope $\pm$ SE ^a	χ^2 (df) ^b	P ^c		
Spinetoram	327	2.14 $\pm$ 0.24	1.54 (4)	0.82	0.02 (0.01–0.03) a	0.06 (0.04–0.08) a
Chlorantraniliprole	435	1.48 $\pm$ 0.16	3.23 (6)	0.78	0.02 (0.01–0.03) a	0.08 (0.06–0.15) ab
Chlorfenapyr	324	1.99 $\pm$ 0.20	6.34 (4)	0.18	0.05 (0.04–0.07) ab	0.24 (0.16–0.35) bc
Indoxacarb	336	2.06 $\pm$ 0.22	6.95 (4)	0.14	0.10 (0.07–0.12) ab	0.42 (0.30–0.59) c
Thiodicarb	332	1.01 $\pm$ 0.10	8.56 (4)	0.07	0.17 (0.13–0.25) b	3.20 (1.64–6.25) d
Flubendiamide	384	1.27 $\pm$ 0.15	3.51 (5)	0.62	0.58 (0.42–0.80) c	5.90 (3.68–9.45) e
Triflumuron	365	0.99 $\pm$ 0.13	3.92 (5)	0.56	4.29 (2.96–6.20) d	84.14 (40.67–174.07) f

^aSE = standard error.^bdf = degrees of freedom.^cP > 0.05 in the goodness-of-fit test indicated good fit to the probit model.^dLC₅₀ and LC₉₀ values followed by different letters within a column are significantly different according to the z-test (P < 0.05).

1 spinetoram, chlorantraniliprole, chlorfenapyr,
 2 indoxacarb and thiodicarb ($\leq 3.20 \mu\text{g a.i./cm}^2$ of diet)
 3 exhibited higher lethality than flubendiamide (5.90
 4 $\mu\text{g a.i./cm}^2$ of diet) and triflumuron ($84.14 \mu\text{g a.i./cm}^2$
 5 of diet) (Table 2).

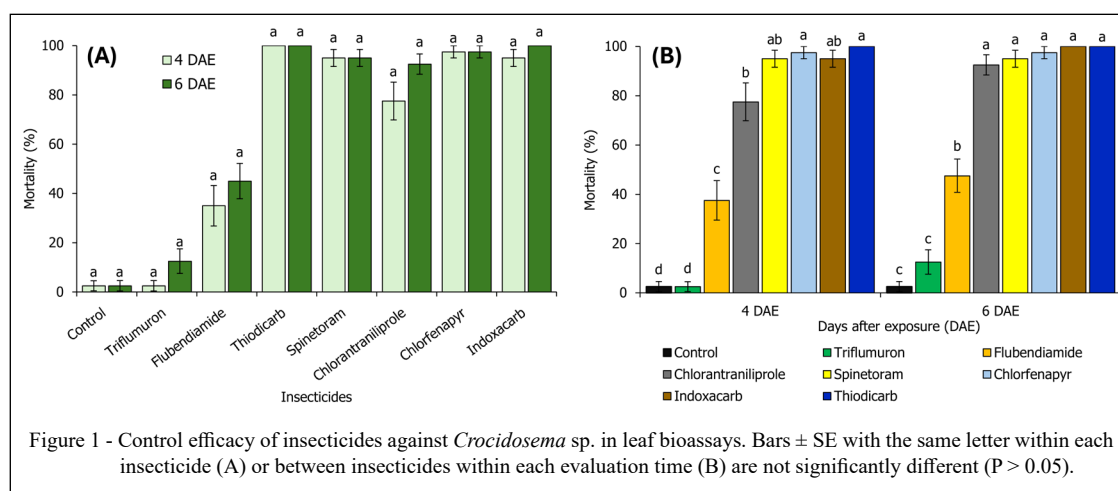
6 Leaf bioassays

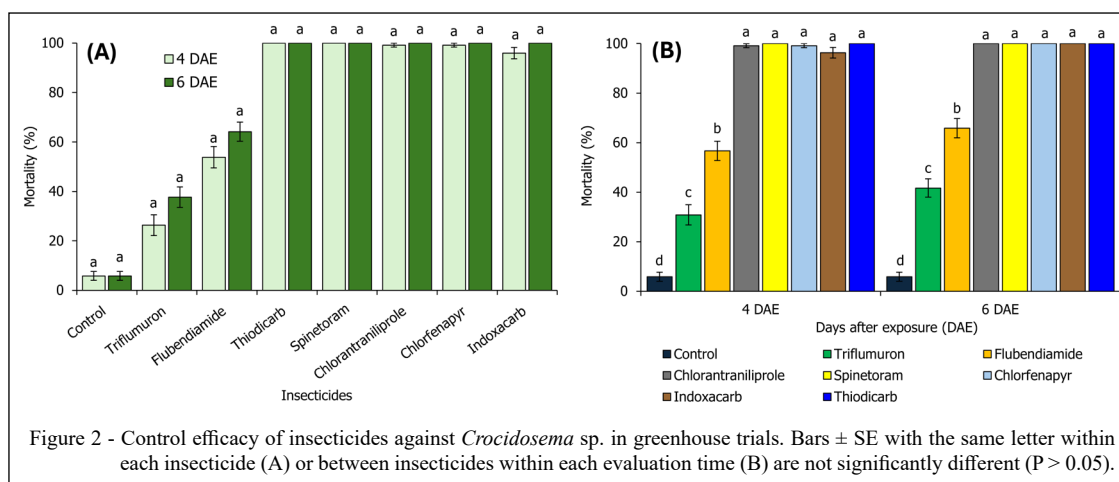
7 The insecticide $\times$ evaluation time
 8 interaction was not significant ($F = 1.03$; $df = 7$,
 9 303 ; $P = 0.4087$), and evaluation time alone did not
 10 influence larval mortality ($F = 4.64$; $df = 1$, 303 ; $P =$
 11 0.0717). In contrast, insecticide treatments strongly
 12 affected mortality of L2 larvae of *Crociosema*
 13 sp. in leaf bioassays ($F = 207.76$; $df = 7$, 303 ; $P <$
 14 0.0001). Mortality at 4 and 6 DAE was similar
 15 between field doses (Figure 1A). Chlorantraniliprole
 16 (>77%), spinetoram and indoxacarb (both >95%),
 17 and chlorfenapyr and thiodicarb (both 100%) caused

substantial higher mortality than flubendiamide
 (<48%) and triflumuron (<13%) (Figure 1B).
 Mortality in untreated controls remained <3%.

5 Greenhouse trials

6 The main effects of insecticide $\times$ evaluation
 7 time interaction and evaluation time alone on mortality
 8 of L2 larvae of *Crociosema* sp. in greenhouse trials
 9 were not significant ($F = 1.41$; $df = 7$, 299 ; $P =$
 10 0.2003 for interaction; and $F = 4.03$; $df = 1$, 299 ; $P =$
 11 0.0660 for evaluation time). As observed in the leaf
 12 bioassays, insecticide treatments had a significantly
 13 effect on larval mortality ($F = 591.77$; $df = 7$, 299 ; P
 14 < 0.0001). Mortality did not differ between 4 and 6
 15 DAE to the tested insecticides (Figure 2A). Across
 16 evaluation times, chlorantraniliprole, spinetoram,
 17 chlorfenapyr, indoxacarb and thiodicarb caused >96%
 18 mortality, whereas flubendiamide (<66% mortality)





1 and triflumuron (<42% mortality) were less effective.
2 Mortality in untreated controls was <6%.

4 DISCUSSION

6 To our knowledge, this is the first report
7 on the susceptibility of *Crociosema* sp. to modern
8 insecticides in South America. *Crociosema* sp.
9 exhibited higher susceptibility to spinetoram,
10 indoxacarb, and thiodicarb (nerve-action insecticides),
11 chlorantraniliprole (a muscle-action insecticide), and
12 chlorfenapyr (a respiration-action insecticide) than
13 flubendiamide (another muscle-action insecticide)
14 and triflumuron (a chitin synthesis inhibitor). Studies
15 conducted during the 1970s and 80s also reported
16 high efficacy, ranging from 72% to 90% control, of
17 older nerve-action insecticides (methamidophos,
18 monocrotophos, carbaryl, chlorpyrifos, and acephate)
19 against *Crociosema* sp. when evaluated 7 days after
20 application at the highest rates tested (FOERSTER,
21 1978; FOERSTER & MATIOLI, 1986). However,
22 some of these insecticides, particularly methamidophos
23 and monocrotophos, are currently banned in Brazil.
24 In contrast, the relatively low efficacy of modern
25 insecticides such as flubendiamide and triflumuron
26 against *Crociosema* sp. was unexpected, given the
27 historically limited exposure of this pest to these
28 compounds in Brazilian soybean production. The
29 factors underlying this reduced susceptibility remain
30 unclear and warrant further investigation.

31 The field-evolved resistance to Cry1Ac
32 soybean in *Crociosema* sp. in Brazil is likely to
33 increase insecticide applications for their management
34 in soybean. According to HAYASHIDA et al. (2023),
35 the use of chemical control against *Crociosema* sp.
36 is indicated only when the economic threshold is

reached (50% and 30% of soybean plants attacked
at vegetative and reproductive stages, respectively).
From an IPM perspective, this soybean pest can be
satisfactorily controlled with most of the chemicals
tested here. However, it is important to highlight that
the same insecticides also have high toxicity against
other lepidopteran pests that infest soybean in Brazil
and neighbouring countries, including *Chrysodeixis*
includens (Walker), *Rachiplusia nu* (Guenée)
(Lepidoptera: Noctuidae), *Anticarsia gemmatilis*
Hübner (Lepidoptera: Erebiidae) and species of the
Spodoptera complex (MACHADO et al., 2022;
BRAGA et al., 2024; GODOY et al., 2024). Therefore,
the accurate identification of lepidopteran species,
together with systematic field monitoring, is essential
for guiding insecticide applications and effectively
managing the soybean lepidopteran complex.

From an IRM perspective, the high
lethality of insecticides against both primary and
secondary lepidopteran soybean pests support the use
of rotation schemes to delay resistance. *Bt* soybean
varieties expressing Cry1A.105/Cry2Ab2/Cry1Ac
and Cry1Ac/Cry1F toxins can also improve control
of key lepidopteran pests, including *Crociosema*
sp., and the management of resistance to chemicals.
Overall, these findings provide practical guidance for
managing *Crociosema* sp. in soybean in Brazil and
other South American countries.

CONCLUSION

The present study demonstrated that
Crociosema sp. is more susceptible to insecticides
containing spinetoram, chlorantraniliprole,
chlorfenapyr, indoxacarb, and thiodicarb than to
flubendiamide and triflumuron, highlighting these

active ingredients as more effective options for their control in soybean.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE

No AI tools were used in the preparation of this manuscript.

REFERENCES

- ABBOTT, W. S. A method of computing the effectiveness of an insecticide. **Journal of Economic Entomology**, v.18, n.2, p.265–266, 1925. Available from: <<https://academic.oup.com/jee/article-abstract/18/2/265/785683?redirectedFrom=fulltext>>. Accessed: Aug. 10, 2025. doi:10.1093/jee/18.2.265a.
- ALTESOR, P. et al. Reproductive behaviour of *Crociosema* (= *Epinotia*) *aporema* (Walsingham) (Lepidoptera: Tortricidae): temporal pattern of female calling and mating. **Neotropical Entomology**, v.39, n.3, p.324–329, 2010. Available from: <<https://www.scielo.br/j/ne/a/VTDhrmmSmzhfzqV9ZnDtP5z/?lang=en>>. Accessed: Jul. 15, 2025. doi: 10.1590/S1519-566X2010000300003.
- BARTLETT, M. S. Properties of sufficiency and statistical tests. **Proceedings of the Royal Society of London - Series A: Mathematical and Physical Sciences**, v.160, n.901, p.268–282, 1937. Available from: <<https://royalsocietypublishing.org/rspa/article/160/901/268/5611/Properties-of-sufficiency-and-statistical-tests>>. Accessed: May, 02, 2025. doi: 10.1098/rspa.1937.0109.
- BENTANCOURT, C; SCATONI, I. **Lepidópteros de importância económica en el Uruguay**: Reconocimiento, Biología y Daños de las Plagas Agrícolas y Forestales. Uruguay: Universidad de la República Facultad de Agronomía, 1989, 56p. Notas Técnicas,7.

Available from: <<https://www.colibri.udelar.edu.uy/jspui/handle/20.500.12008/32905>>. Accessed: May, 08, 2025.

BIEZANKO, C. M. Olethreutidae, Tortricidae, Phalonidae, Aegeriidae, Glyphipterygidae, Yponomeutidae, Gelechiidae, Oecophoridae, Xylorictidae, Lithocolletidae, Cecidoseidae, Ridiaschinidae, Acrolophidae, Tineidae e Psychidae da zona sudeste do Rio Grande do Sul. **Arquivos de Entomologia da Escola de Agronomia “Eliseu Maciel”**, Série A, p.1-16, 1961. Available from: <<https://citeseerx.ist.psu.edu/document?doi=622696212caf23b43057dce4d4778e124903d490&repid=rep1&type=pdf>>. Accessed: Sept. 06, 2025.

BRAGA, L. E. et al. Characterizing the differential susceptibility and resistance to insecticides in populations of *Chrysodeixis includens* and *Rachiplusia nu* (Lepidoptera: Noctuidae) in Brazil. **Pest Management Science**, v.80, n.10, p.4853–4862, 2024. Available from: <<https://scijournals.onlinelibrary.wiley.com/doi/10.1002/ps.8197>>. Accessed: Aug. 25, 2025. doi: 10.1002/ps.8197.

FERREIRA, B. S. C. Sampling *Epinotia aporema* on soybean. In: M. KOGAN & D. C. HERZOG (Eds), **Sampling Methods in Soybean Entomology**, Springer Nature, p.374–381, 1980. Available from: <https://link.springer.com/chapter/10.1007/978-1-4612-9998-1_18>. Accessed: May, 12, 2025. doi: 10.1007/978-1-4612-9998-1_18.

FERNANDES, D. S. et al. Molecular characterization and demographic insights into soybean bud borer (Lepidoptera: Tortricidae) in Brazil. **Journal of Insect Science**, v.24, n.2, p.1–9, 2024. Available from: <<https://academic.oup.com/jinsectscience/article/24/2/5/7624479>>. Accessed: Jul. 27, 2025. doi: 10.1093/jisesa/ieae019.

FOERSTER, L. A.; MATIOLI, J. C. Insecticide lures and chemical control of the soybean stem borer *Epinotia aporema* (Walsingham, 1914) (Lepidoptera, Tortricidae). **Anais da Sociedade Entomológica do Brasil**, v.15, n.2, p.361–369, 1986. Available from: <<https://anais.seb.org.br/index.php/aseb/article/view/435>>. Accessed: Sept. 03, 2025. doi: 10.37486/0301-8059.v15i2.435.

FOERSTER, L. A. Controle químico da broca das axilas *Epinotia aporema* (Walsingham, 1914) em soja no Paraná. **Anais da Sociedade Entomológica do Brasil**, v.7, n.1, p.3–6, 1978. Available from: <<https://anais.seb.org.br/index.php/aseb/article/view/132>>. Accessed: Oct. 22, 2025. doi: 10.37486/0301-8059.v7i1.132.

GODOY, D. N. et al. Susceptibility of Brazilian populations of *Rachiplusia nu* (Lepidoptera: Noctuidae) to insecticides and determination of diagnostic concentrations for a proactive resistance management program. **Pest Management Science**, v.81, n.4, p.1829–1839, 2024. Available from: <<https://scijournals.onlinelibrary.wiley.com/doi/10.1002/ps.8580>>. Accessed: Nov. 07, 2025. doi: 10.1002/ps.8580.

HAYASHIDA, R. et al. Re-evaluation of the economic threshold for *Crociosema aporema* injury to indeterminate *Bt* soybean cultivars. **Agronomy Journal**, v.115, n.4, p.1972–1980, 2023. Available from: <<https://access.onlinelibrary.wiley.com/doi/10.1002/agj2.21339>>. Accessed: Oct. 05, 2025. doi: 10.1002/agj2.21339.

HORIKOSHI, R. J. et al. Large-scale assessment of lepidopteran soybean pests and efficacy of Cry1Ac soybean in Brazil. **Scientific Reports**, v. 11, n. p.15956, 2021a. Available from: <<https://www>>.

- 1 nature.com/articles/s41598-021-95483-9>. Accessed: Sept. 09,
2 2025. doi: 10.1038/s41598-021-95483-9.
- 3 HORIKOSHI, R. J. et al. Resistance status of lepidopteran soybean
4 pests following large-scale use of MON 87701 × MON 89788 soybean
5 in Brazil. **Scientific Reports**, v.11, n.21323, 2021b. Available from:
6 <<https://www.nature.com/articles/s41598-021-00770-0>>. Accessed:
7 Apr. 11, 2025. doi: 10.1038/s41598-021-00770-0.
- 8 INSECTICIDE RESISTANCE ACTION COMMITTEE (IRAC).
9 **Susceptibility Test Method 017**: Codling Moth (*Cydia pomonella*)
10 Larvae – Diet Method. Available from: <[https://irac-online.org/](https://irac-online.org/methods/cydia-pomonella-larvae/)
11 [methods/cydia-pomonella-larvae/](https://irac-online.org/methods/cydia-pomonella-larvae/)>. Accessed: Sept. 05, 2025.
- 12 LILJESTRÖM, G. G. et al. Resource utilization and larval
13 survival of the bud borer, *Crociosema aporema* (Lepidoptera:
14 Tortricidae), in soybean (*Glycine max*). **Ecología Austral**, v.11, n.2,
15 p.87–94, 2001. Available from: <[https://bibliotecadigital.exactas.](https://bibliotecadigital.exactas.uba.ar/greenstone3/eva/collection/ecologiaaustral/document/ecologiaaustral_v011_n02_p087)
16 [uba.ar/greenstone3/eva/collection/ecologiaaustral/document/](https://bibliotecadigital.exactas.uba.ar/greenstone3/eva/collection/ecologiaaustral/document/ecologiaaustral_v011_n02_p087)
17 [ecologiaaustral_v011_n02_p087](https://bibliotecadigital.exactas.uba.ar/greenstone3/eva/collection/ecologiaaustral/document/ecologiaaustral_v011_n02_p087)>. Accessed: Jul. 06, 2025.
- 18 LILJESTRÖM, G. G.; ROJAS-FAJARDO, G. Larval parasitism
19 of *Crociosema* (= *Epinotia*) *aporema* (Lepidoptera: Tortricidae)
20 in north-eastern Buenos Aires province (Argentina). **Revista de la**
21 **Sociedad Entomológica Argentina**, v.64, n.1-2, p.37–44, 2005.
22 Available from: <[https://www.scielo.org.ar/scielo.php?script=sci_ar](https://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S0373-56802005000100009)
23 [ttext&pid=S0373-56802005000100009](https://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S0373-56802005000100009)>. Accessed: Sept. 23, 2025.
- 24 MACHADO, E. P. et al. Interspecific variation in susceptibility to
25 insecticides by lepidopteran pests of soybean, cotton, and maize
26 crops from Brazil. **Journal of Economic Entomology**, v.115, n.1,
27 p.305–312, 2022. Available from: <[https://academic.oup.com/](https://academic.oup.com/jee/article/115/1/305/6498044)
28 [jee/article/115/1/305/6498044](https://academic.oup.com/jee/article/115/1/305/6498044)>. Accessed: May, 29, 2025. doi:
29 10.1093/jee/toab265.
- 30 MORAL, R. A. et al. Half-normal plots and over dispersed models
31 in R: the *hnp* package. **Journal of Statistical Software**, v.81, n.10,
32 p.1–23, 2017. Available from: <[https://www.jstatsoft.org/article/view/](https://www.jstatsoft.org/article/view/v081i10)
33 [v081i10](https://www.jstatsoft.org/article/view/v081i10)>. Accessed: Nov. 23, 2025. doi: 10.18637/jss.v081.i10.
- 34 PANIZZI, A. R. History, and contemporary perspectives of the
integrated pest management of soybean in Brazil. **Neotropical**
Entomology, v.42, p.119–127, 2013. Available from: <[https://link.](https://link.springer.com/article/10.1007/s13744-013-0111-y)
[springer.com/article/10.1007/s13744-013-0111-y](https://link.springer.com/article/10.1007/s13744-013-0111-y)>. Accessed: Jun.
12, 2025. doi: 10.1007/s13744-013-0111-y.
- PEREYRA, P. C.; SÁNCHEZ, N. E. Effects of different host-plant
species on growth, development and feeding of the bud borer,
Epinotia aporema (Lepidoptera: Tortricidae) in La Plata, Argentina.
Revista Chilena de Historia Natural, v.71, n.3, p.269–275,
1997. Available from: <[https://rchn.biologiachile.cl/pdfs/1998/3/](https://rchn.biologiachile.cl/pdfs/1998/3/Pereyra_%20Sanchez_1998.pdf)
[Pereyra_%20Sanchez_1998.pdf](https://rchn.biologiachile.cl/pdfs/1998/3/Pereyra_%20Sanchez_1998.pdf)>. Accessed: Aug. 05, 2025.
- R CORE TEAM. **R**: A Language and Environment for Statistical
Computing. R Foundation for Statistical Computing, Vienna,
Austria, 2021. Available from: <<https://www.R-project.org/>>.
Accessed: Jul. 10, 2025.
- ROBERTSON, J. L. et al. Bioassays with Arthropods: Boca Raton,
FL: **CRC Press**, v.2 n.13, p.224, 2017. Available from: <[https://](https://api.taylorfrancis.com/content/books/mono/download?identifierName=doi&identifierValue=10.1201/9781315373775&type=googlepdf)
[api.taylorfrancis.com/content/books/mono/download?identifierNa](https://api.taylorfrancis.com/content/books/mono/download?identifierName=doi&identifierValue=10.1201/9781315373775&type=googlepdf)
me=doi&identifierValue=10.1201/9781315373775&type=google
pdf>. Accessed: Sept. 17, 2025.
- SÁNCHEZ, N. E.; PEREYRA, P. C. Neotropical soybean bud
borer, *Crociosema aporema* (Walsingham, 1914) (Lepidoptera:
Tortricidae). In: **Encyclopedia of Entomology**. 2nd ed. JL
Capinera, p.2587–2588, 2008. Available from: <[https://archive.](https://archive.org/details/CapineraEncyclopediaOfEntomology2espringer2008)
[org/details/CapineraEncyclopediaOfEntomology2espringer2008](https://archive.org/details/CapineraEncyclopediaOfEntomology2espringer2008)>.
Accessed: Oct. 12, 2025.
- SAS INSTITUTE INC. SAS/STAT: Statistical Analysis System:
getting started with the SAS learning. Version 9.1. Cary, NC: SAS
Institute, 2002.
- SHAPIRO, S. S.; WILK, M. B. An analysis of variance test for
normality (complete samples). **Biometrika**, v.52, n.3-4, p.591–611,
1965. Available from: <[https://www.jstor.org/stable/2333709?origin](https://www.jstor.org/stable/2333709?origin=crossref&seq=1)
=crossref&seq=1>. Accessed: Nov. 04, 2025. doi: 10.2307/2333709.
- STEINHAUS, E. A. et al. Characterization of resistance to *Bacillus*
thuringiensis toxin Cry1Ac in *Crociosema* sp. (Lepidoptera:
Tortricidae) from Brazil. **Pest Management Science**, v.81,
n.6, p.3066–3073, 2025. Available from: <[https://scijournals.](https://scijournals.onlinelibrary.wiley.com/doi/10.1002/ps.8679)
[onlinelibrary.wiley.com/doi/10.1002/ps.8679](https://scijournals.onlinelibrary.wiley.com/doi/10.1002/ps.8679)>. Accessed: Sept.
25, 2025. doi:10.1002/ps.8679.

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