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Original Article

Efficacy of microbiological and chemical insecticides as alternatives for control of *Myochrous armatus* (Baly, 1865) (Coleoptera: Chrysomelidae)

Eficácia de inseticidas microbiológicos e químicos como alternativas para controle de *Myochrous armatus* (Baly, 1865) (Coleoptera: Chrysomelidae)

M. C. Jean-Baptiste[a], A. Lima de Brida[b,c] and F. R. M. Garcia[d*]

[a]Universidade Federal de Pelotas – UFPel, Programa de Pós-graduação em Fitossanidade, Pelotas, RS, Brasil
[b]Universidade Pitagoras Unopar, São Gabriel do Oeste, MS, Brasil
[c]CropSolutions - Pesquisa, Tecnologia e Inovação Agropecuária Ltda., São Gabriel do Oeste, MS, Brasil
[d]Universidade Federal de Pelotas – UFPel, Instituto de Biologia, Departamento de Ecologia de Insetos, Zoologia e Genética, Pelotas, RS, Brasil

Abstract

Myochrous armatus (Baly, 1865) (Coleoptera: Chrysomelidae) causes considerable losses to soybean crops in Brazil and several other South American countries. Applying biological insecticides can be an effective alternative to suppressing this pest. The objective of this study was to assess the efficacy of microbiological insecticides formulated from the fungi *Beauveria bassiana* + *Metarhizium anisopliae* (Bometil) and *B. bassiana* alone (Ballvéria), and the bacterium *Bacillus thuringiensis* (Acera) alone and in combination with the chemical insecticides fipronil, ethiprole and chlorpyrifos, against *M. armatus* adults. The insecticides based on *B. bassiana* + *M. anisopliae* were found to be more pathogenic than those based on *B. bassiana,* causing cumulative mortality rates in the ten days of 85.0 and 65.0% respectively. In contrast, *B. thuringiensis* caused 92.5% mortality. These products alone and in combination were effective for control at their lowest concentrations. Therefore, the use of microbiological insecticides individually or in combination with chemical insecticides is a promising alternative for the integrated management of *M. armatus*.

Keywords: microbiological insecticides, chemical insecticides, soybean mealworm, alternatives control.

Resumo

Myochrous armatus (Baly, 1865) (Coleoptera: Chrysomelidae) causa perdas consideráveis às lavouras de soja no Brasil e em vários outros países da América do Sul. A aplicação de inseticidas biológicos pode ser uma alternativa eficaz para suprimir esta praga. O objetivo deste estudo foi avaliar a eficácia de inseticidas microbiológicos formulados a partir dos fungos *Beauveria bassiana* + *Metarhizium anisopliae* (Bometil) e *B. bassiana* (Ballvéria), e bactéria *Bacillus thuringiensis* (Acera) isoladamente e em combinação com os inseticidas químicos fipronil, etiprole e clorpirifós, contra adultos de *M. armatus*. Os inseticidas à base de *B. bassiana* + *M. anisopliae* foram mais patogênicos que os à base de *B. bassiana*, causando taxas de mortalidade acumuladas nos dez dias com 85,0 e 65,0% respectivamente. Em contraste, *B. thuringiensis* causou 92,5% de mortalidade. Estes produtos sozinhos e em combinação foram eficazes para o controlo nas suas concentrações mais baixas. Portanto, o uso de inseticidas microbiológicos individualmente ou em combinação com inseticidas químicos é uma alternativa promissora para o manejo integrado de *M. armatus*.

Palavras-chave: inseticidas microbiológicos, inseticidas químicos, cascudinho-da-soja, alternativas de controle.

1. Introduction

Soybean is one of the world's most important crops (Lin et al., 2022), with production of 383.31 million metric tons (Mt) in the 2022-2023 harvest, from an estimated cultivated area of 135.55 million hectares. More than 90% of this output came from Brazil (153.0 Mt), the United States (116.38 Mt), Argentina (41.0 Mt), China (20.33 Mt), India (12.0 Mt), Paraguay (10.0 Mt), Canada (6.54 Mt) and Uruguay (2.30 Mt) (USDA, 2023).

Among soybean pests, *Myochrous armatus* (Baly, 1865) (Coleoptera: Chrysomelidae), popularly known as cane leaf or bud beetle, stands out. It has an average length of 5 mm, an oval shape, and dark gray, brown, or black color, always with darker or lighter spots (Hoffmann-Campo, 2002). Adults significantly reduce the productivity of soybean plants by attacking newly emerged plants, damaging the cotyledons, and causing small irregular lesions on the

*e-mail: flavio.garcia@ufpel.edu.br
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stem or cuts on the petiole and defoliation, leading to death (Degrande and Vivan, 2010).

Management of *M. armatus* is mainly based on synthetic chemical pesticides due to their rapid action. The pesticide most often used to control the pest is fipronil, a neurotoxic substance of the phenylpyrazole group (Yii et al., 2016). It is considered to be the "gold standard" treatment to control the *M. armatus* (Perini and Pereira, 2022).

In the Brazilian state of Mato Grosso do Sul, infested soybean crops are also treated with some insecticides of the chemical groups cypermethrin + profanophos (1 L/ha), acephate (1 kg/ha), chlorpyrifos (1.5 L/ha) or esfenvalerate + fenitrothion (0.5 L/ha) (Perini and Pereira, 2022). The low resistance of the pesticide requires multiple prophylactic spray applications to prevent reinfestation by the pest, but the intensive use of these products can harm the environment and human health. Therefore, alternative control methods with low environmental impact should be studied, such as the use of entomopathogenic fungi (EPF). These fungi are considered to be promising mealworm biocontrol agents. Many studies have found that biological control of crop pests by application of microbiological insecticides is a viable alternative, since these agents stand out for their host specificity and innocuousness to beneficial insects, besides conserving and protecting agroecosystems (Alves et al., 2008). The microbiological insecticides based on *Beauveria bassiana* and *Metarhizium anisopliae* are among the main microbial control agents. The possibility of combining these fungi with different chemical compounds to obtain varied formulations along with their ease of production makes these pathogens global commercial leaders (Jin et al., 2008). Bometil, Ballvéria, and Acera are three commercial biocontrol products sold in Brazil, formulated from a mixture of isolates of the EPF *B. bassiana* + *M. anisopliae, B. bassiana,* and *B. thuringiensis*. They are considered entomopathogenic because they act like a disease in the insect by penetrating the cuticle, colonizing the internal organs, and releasing harmful substances that prevent the insect from feeding, and killing it (Ballagro Agro Technologia, 2023).

The use of biopesticides can protect crops while reducing dependence on synthetic insecticides. In particular, EPF has the potential to adapt to different environmental and climate conditions and minimize populations of target pests that attack various crops (Meyling and Eilenberg, 2007; Zimmermann, 2008; Martínez et al., 2022). However, the effect of EPF is unstable, since they are easily influenced by abiotic and biotic factors such as soil parameters or their interaction. In the majority of cases, these factors interfere with each phase of the fungal life cycle (Mora et al., 2016).

EPF formulations are also considered slow-acting microbiological insecticides because they take longer than synthetic chemicals to cause mortality of insect pests. To increase the killing speed, it is possible to use compatible mixtures of EPF with sublethal concentrations of the main synthetic chemical insecticide. The EPF can act synergistically with these insecticides to hasten and increase the mortality of the target pests (Sharififard et al., 2011; Bitsadze et al., 2013). For effective control, the combined use of EPF such as *B. bassiana* and *M. anisopliae* with low doses of chemical insecticides is a promising option for pest control. In particular, the low insecticide dosage reduces environmental contamination and the development of pest resistance (Nawaz et al., 2022).

Research into microbiological insecticides as environmentally friendly alternatives to conventional insecticides is necessary for the control of *M. armatus* through integrated management programs. In this context, the objective of this study was to evaluate the efficacy of microbiological and chemical insecticides against *M. armatus* adults.

2. Material and methods

2.1. Study site

The study was conducted in the Entomology Laboratory of the research station of the company CropSolutions, located in the municipality of São Gabriel do Oeste, Mato Grosso do Sul State (19°27'42,61" South latitude Sul and 54°36'59,51" West longitude, altitude of 58 meters). The research station is accredited by the Brazilian Agriculture Ministry (MAPA) for the conduction of Temporary Special Registration (RET) tests.

2.2. Insect samples

M. armatus specimens were collected in a soybean field at the CropSolutions research station in a receptacle (1000 mL) and PET bottles (1.5 L) (Polyethylene Terephthalate). closed with perforated lids (five holes per lid with 1 mm diameter) to permit the exchange of air. The specimens were taken to the laboratory where they were allowed to feed for 24 hours on soybean leaves.

2.3. Chemical insecticide and bioinsecticide formulations and treatments

We used formulations composed of water-dispersible granules (WG), concentrated suspensions (CS) and emulsifiable concentrates (EC) of the following chemical insecticides: (i) Fipronil 800 WG CCAB (CCAB AGRO S.A. Alameda Santos, Cerqueira César, São Paulo, Brazil), containing an 80% concentration of the active ingredient (AI) fipronil; (ii) Curbix 200 CS (Bayer S.A., São Paulo, Brazil), containing a 20.0% concentration of the AI ethiprole; and (iii) Chlorpyrifos 480 EC (Nortox S.A. Arapongas, Paraná, Brazil), containing a 20.0% concentration of the AI chlorpyrifos. In turn, the microbiological insecticides were formulated from emulsifiable concentrates (EC) and wettable powder (WP) of: (i) Bometil 300 g/kg (Ballagro AgroTecnologia Ltda., São Paulo, Brazil), containing a 15% concentration of the AI *B. bassiana,* Isolate IBCB 66 (4.3×10^8 ufc g^{-1}) + 15% of the AI *M. anisopliae,* Isolate IBCB 425 (3.2×10^8 ufc g^{-1}); (ii) Ballvéria 300g/kg (Ballagro AgroTecnologia Ltda., São Paulo, Brazil), containing a 30% concentration of the AI *B. bassiana,* Isolate IBCB 66 (1.0×10^9 ufc g^{-1}); and (iii) Acera 64g/L (Ballagro AgroTecnologia Ltda., São Paulo, Brazil), containing a 6.4% concentration of the AI *B. thuringiensis*, Isolates 1641 and 1644 (1.3×10^9 viable spores mL^{-1}). The chemical insecticides were tested individually and in combination at the recommended concentrations, while the microbiological insecticides were tested in the concentrations recommended by the manufacturer alone and in combination with the chemical insecticides. The microbiological insecticides were based on the EPF *B. bassiana* and *M. anisopliae* and the bacterium *B. thuringiensis* (Table 1).

2.4. Bioassays

2.4.1. Effect of recommended doses of chemical and microbiological insecticides on mortality of M. armatus adults

The experimental design was entirely randomized with thirteen treatments, each with eight repetitions (Petri dishes with 9 cm diameter lined with two filter paper sheets) and 5 *M. armatus* adults per dish, for a total of 40 *M. armatus* adults per treatment. The products (treatments) used were: Fipronil (800 WGCCAB); Curbix (200 SC); Chlorpyrifos (480 EC); *B.* Bometil (300 WP); Ballvéria 300 WP); Bometil (300 WP) + Fipronil (800 WGCCAB); Ballvéria (300 WP) + Fipronil (800 WGCCAB); Bometil (300 WP) + Curbix (200 SC); Ballvéria (300 WP) + Curbix (200 SC); Bometil (300 WP) + Chlorpyrifos (480 EC); Ballvéria (300 WP) + Chlorpyrifos (480 EC) and Acera (64 EC). Distilled water served as the negative control. The chemical and microbiological insecticides were prepared at the concentrations of the active ingredients described in Table 1 (water + chemical and/or microbiological insecticide) in PET bottles with 1.5 L capacity. A 1 mL suspension of each chemical and biological insecticide was applied in each bottle separately or in combination at the recommended concentrations (Table 1). The bottles were shaken manually for approximately 5 seconds before application. The suspension of each solution was applied with a pressure sprayer (Vonder 1.5 L) once ≈ 1 mL) on the surface of the Petri dishes containing *M. armatus* adults. The dishes were then sealed with PVC film and kept in a climate-controlled room (temperature of 25 ± 2 °C, relative humidity of 70 ± 10%, and 12/12 hour photophase). The dishes were evaluated at 3, 7, and 10 days after application (DAA). The dead *M. armatus* adults were then placed in Petri dishes with 9 cm diameter lined with 2 filter paper sheets. The dishes were sealed with PVC film, identified, and stored in a BOD incubator (Biochemical Oxygen Demand) at a temperature of 25 ± 3 °C, relative humidity of 70 ± 10%, and 24-hour photoperiod) for 10 days for growth of fungal colonies.

2.5. Statistical analysis

Initially, data on accumulated mortality (%) at 3, 7, and 10 days of evaluation after treatment and several living *M. armatus* adults were subjected to the Shapiro-Wilk normality and Bartlett homoscedasticity of variance tests. We used the nonparametric Kruskal-Wallis test and variance analysis (ANOVA) to verify the differences between treatments. The post hoc test ($p<0.05$) was then performed using Dunn-Bonferroni tests to verify the data that do not meet the assumptions of normality and homogeneity of variances and for adjustment of *P* values. These analyses were performed in the R software Version 4.2.3 (R Development Core Team, 2023).

3. Results

3.1. Effect of chemical and microbiological insecticides on M. armatus adults

All the treatments had significant insecticidal activity against *M. armatus* when applied alone and in various combinations. However, the combined treatments were more effective than the individual ones. Each chemical product (fipronil, ethiprole, chlorpyrifos) and microbiological product (Ballvéria, Bometil, Acera) had different insecticidal effects on *M. armatus* adults. The insects attacked by the fungi had a whitish or slightly yellowish color on both sides of the tegument and died when the fungal reproductive structures covered the entire body (Figure 1).

3.2. Effect of recommended doses of chemical and microbiological insecticides on the mortality of M. armatus adults

There were statistical differences ($p < 0.05$) in the cumulative mortality of *M. armatus* adults in the function of the chemical and microbiological insecticides 10 days after application (DAA) of the products. The susceptibility of the insects to the products (microbiological and chemical)

Table 1. Commercial chemical and microbiological insecticides used in the laboratory bioassays against *Myochrous armatus*.

Active ingredient	[a]Dose (c.p.)	Trade name	Chemical group
Fipronil	0.262g/L	Fipronil® 80WG CCAB	Pyrazole
Ethiprole	2.5 g /L	Curbix® 8 200 CS	Phenylpyrazole
Chlorpyrifos	8.0 mL/L	Chlorpyrifos® 8 480 EC	Organophosphorus
Beauveria bassiana IBCB 66	2.0 g/L	Bometil® 8 300 WP	Microbiological insecticide
Metarhizium anisopliae IBCB 425			
Beauveria bassiana IBCB 66	2.0 g/ L	Ballvéria® 8 300 WP	Microbiological insecticide
Bacillus thuringiensis IBCB 1641+1644	5.0 mL/L	Acera® 8 64 EC	Microbiological insecticide

[a]Dose g or mL of c.p. (commercial product)/1 liter of water; IBCB = Brazilian Biological Control Institute; WG = Water-dispersible Granules; CS = Concentrated Suspension; EC = Emulsifiable Concentrate; WP = Wettable Powder.

varied. While in all treatments the mortality increased with time, the rates of this increase were different.

Application of all the insecticides tested alone or in combination (chemical + microbiological) resulted in 100% mortality of the insects (Table 2). One DAA, fipronil (87.5%), ethiprole (80.0%), and *B. bassiana* + *M. anisopliae* + chlorpyrifos (55.0%) caused mortality of the *M. armatus* adults greater than 50.0% (F = 96.79; d.f. = 12, 91; p < 0.001) (Table 2). Three DAA, fipronil, ethiprole, and chlorpyrifos caused 100% mortality. The combination of *B. bassiana* + *M. anisopliae* caused 22.5% mortality and did not differ from *B. bassiana* (10.0%) and *B. thuringiensis* (17.5%). The combinations of *B. bassiana* + *M. anisopliae* + chlorpyrifos and *B. bassiana* + chlorpyrifos also caused 100% mortality and the averages differed statistically from those of the combinations of *B. bassiana* + *M. anisopliae* + fipronil (70%), *B. bassiana* + fipronil (60%), *B. bassiana* + *M. Anisopliae* + ethiprole (50%) and *B. bassiana* + ethiprole (42.5%) (F = 178.05; d.f. = 12, 91; p < 0.001) (Table 2). Seven DAA, the mortality rates of the insects due to the application of *B. thuringiensis* (52.5%) and *B. bassiana* + *M. Anisopliae* (55.0%) were statistically identical and differed from the mortality rate caused by *B. bassiana* (35.0%) (F = 108.97; d.f. = 12, 91; p < 0.001) (Table 2). Ten DAA, the mortality rate from treatment with *B. thuringiensis* (92.5%) differed significantly from the rates caused by *B. bassiana* + *M. anisopliae* (85.0%) and *B. bassiana* alone (65.0%) (F = 73.32; d.f. = 12, 91; p < 0.001) (Table 2).

Figure 1. *Myochrous armatus* adults infected with Bometil (*Beauveria bassiana* + *Metarhizium anisopliae*).

The results show a gradual decrease in the number of *M. armatus* insects after the application of the products

Table 2. Cumulative mortality (%) (mean ± SE) of *Myochrous armatus* adults exposed alone and in combinations of different concentrations of chemical and biological products in laboratory conditions to the 1, 3, 7, and 10 days after application of the treatments.

Treatment	Mortality (%)			
	1 day	3 days	7 days	10 days
Fipronil	87.50 ± 3.65 a	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
Ethiprole	80.00 ± 3.77 a	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
Chlorpyrifos	47.50 ± 3.65 b	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
B. bassiana IBC 66 + *M. Anisopliae* IBC 425*	0.00 ± 0.00 d	22.50 ± 4.53 e	55.00 ± 5.00 c	85.00 ± 5.00 a
B. bassiana IBC 66*	0.00 ± 0.00 d	10.00 ± 3.77 of	35.00 ± 5.00 d	65.00 ± 7.31 b
B. bassiana IBC 66 + *M. Anisopliae* IBC 425 + fipronil	45.00 ± 8.23 b	70.00 ± 6.54 b	87.50 ± 3.65 ab	100.00 ± 0.00 a
B. bassiana IBC 66 + fipronil	25.00 ± 5.00 c	60.00 ± 6.26 bc	77.50 ± 4.53 b	87.50 ± 3.77 a
B. bassiana IBC 66 + *M. Anisopliae* IBC 425 + ethiprole	15.00 ± 3.65 cd	50.00 ± 3.77 cd	85.00 ± 5.00 ab	100.00 ± 0.00 a
B. bassiana IBC 66 + ethiprole	12.50 ± 3.65 cd	42.50 ± 2.50 d	77.50 ± 5.90 b	100.00 ± 0.00 a
B. bassiana IBC 66 + *M. Anisopliae* IBC 425+ chlorpyrifos	55.00 ± 5.00 b	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
B. bassiana IBC 66 + chlorpyrifos	42.50 ± 2.50 b	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
B. thuringiensis IBC 1641 + 1644*	2.50 ± 0.94 d	17.50 ± 4.53 e	52.50 ± 5.26 cd	92.50 ± 3.65 a
Control (water)	0.00 ± 0.00 d	0.00 ± 0.00 f	2.500 ± 2.50 e	7.50 ± 3.65 c
F	96.79	178.05	108.97	73.32
d.f	12.91	12.91	12.91	12.91
P	< 0.001	< 0.001	< 0.001	< 0.001

Means (±SE) in each column followed by the same letter (for each day of evaluation) are not statistically significant by the Post hoc test Dunn-Bonferroni, p<0.05. *Bonetil (*Bauveria bassiana*, Isolate IBCB 66 + *Metarhizium Anisopliae*, Isolate IBCB 425), Ballvéria (*Bauveria bassiana*, Isolate IBCB 66), Acera (*Bacllus thuringiensis*, Isolates IBCB 1641 + 1644).

either alone or in combination. One DAA, percentages of mortality ≥ 80% were observed for fipronil and ethiprole, and more than 50% of mortality for the combination of *B. bassiana* + *M. Anisopliae* + chlorpyrifos. At the 3rd DAA, there was a total reduction in the number of living insects in the fipronil and ethiprole treatments, but also in the combination of *B. bassiana* + *M. Anisopliae* + chlorpyrifos and *B. bassiana* + chlorpyrifos. In one DAA of the products, there was a reduction of approximately 33.4% in the average number of live insects in all tests, while between 3 and 7 DAA there was an average reduction of 74.0%, and at 10 DAA the reduction was 88.6% (Figure 2).

4. Discussion

This study focused on the effects of various concentrations of microbiological and chemical insecticides alone and in combination, to ascertain whether the application of formulations consisting of lethal and sublethal doses of the active ingredients can be an alternative strategy for the integrated management of *M. armatus*. Sublethal doses of fipronil and ethiprole enhanced the effect of the microbiological insecticides *B. bassiana* + *M. anisopliae* (Bometil) and *B. bassiana* (Ballvéria) on the mortality of *M. armatus*. In this sense, the use of a combination of microbiological and synthetic chemical insecticides is a reliable alternative (Batista Filho et al., 2001).

We tested two microbiological insecticides with different formulations on *M. armatus*, adults, and found the best to be Bometil, a formulation based on the fungi *B. bassiana* + *M. anisopliae*. In other laboratory studies, the fungus *B. bassiana* applied alone and in combination with chemical insecticides was tested for control of other pests, such as the elm leaf beetle *Xanthogaleruca luteola* Muller (Coleoptera: Chrysomelidae) (Ebrahimifar and Jamshidnia, 2021), Colorado potato beetle *Leptinotarsa decemlineata* Say, 1824 (Coleoptera: Chrysomelidae) (Anderson et al.,

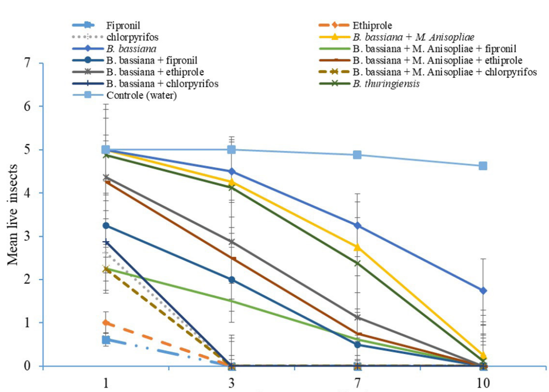

Figure 2. Average number (± SE) of live *Myochrous armatus* adults after the period (days) of exposure to different concentrations of *Beauveria bassiana +Metarhizium anisopliae*, *Beauveria bassiana*, *Bacillus thuringiensis*, fipronil ethiprole and chlorpyrifos, alone and in combinations in the laboratory (temperature = 25 ± 3 °C, relative humidity = 70 ± 10% and 12/12 hour photoperiod). Values represent the means (±SE) of 8 replications.

1989), and boll weevil *Anthonomus grandis* Boheman, 1843 (Coleoptera: Curculionidae) (Lima et al., 2020; Mulock and Chandler, 2001).

The microbiological insecticides based on *B. thuringiensis* (Acera) and *B. bassiana* + *M. anisopliae* (Bometil) caused the greatest mortality in *M. armatus* adults. The differences between the two microbiological products in comparison with other insecticides can be explained by: 1) variations in the virulence of the conidia; 2) variations in the penetration in the host's cuticle; 3) the difference in mode of action of *B. thuringiensis* and *B. bassiana*, which attach to the host cells, and/or 4) the fact that *M. anisopliea* directly penetrates the cuticle. Therefore, the infection process is related to the adherence of conidia to the host's cuticle (Schrank and Vainstein, 2010; Magalhães et al., 2000; Ortiz-Urquiza and Keyhani, 2016).

Other studies have reported the potential use of EPF alone and in combination with pesticides against a wide range of pests. Consolo et al. (2003) analyzed the potential pathogenicity of fungal strains applied alone under laboratory conditions against *Diabrotica speciosa* (Germar, 1824) (Coleoptera: Chrysomelidae) and highlighted the importance of *B. bassiana* (Balsamo) Vuillemin (FHD13) against larvae of this insect, causing mortality of 70%. Ozdemir et al. (2020), also in a laboratory study, reported that *B. bassiana* TR-217 and *M. anisopliae* TR-106 were virulent against *Callosobruchus maculatus* Fabr. 1775 (Coleoptera: Chrysomelidae: Bruchinae), causing up to 100% mortality. Majidi-Shilsar (2019) found that fipronil interacted synergistically with *B. bassiana*, causing 54.29% mortality of *Chilo suppressalis* Walker, 1863 (Lepidoptera: Pyralidae). Additionally, Wakil et al. (2012) reported that the combined toxicity of fipronil and *M. anisopliae* increased the mortality of the American cockroach (*Periplaneta americana*). In Brazil, fipronil and ethiprole are registered for sale as active ingredients in various formulations for control of pests, such as *Sternechus subsignatus* Boh, 1836 (Coleoptera: Curculionidae), through foliar and soil application to protect potato, sugarcane and corn crops (Brasil, 2022).

The virulence of the combination of *B. bassiana* + *M. anisopliae* with insecticides was found to be greater than individual use against *Spodoptera litura* Fabricius, 1975 (Lepidoptera: Noctuidae) (Dayakar et al., 2000). Besides this, Wakil et al. (2012) reported the combination of fipronil and *M. anisopliae* increased the mortality of the American cockroach *Periplaneta Americana* Lineu, 1758 (Blattaria: Blattidae).

The better compatibility of fipronil and ethiprole with the microbiological insecticides can explained by the different characteristics of the isolates used since each isolate has different characteristics (Saldanha et al., 2022). Due to their compatibility, the use of these products will preserve the conidia of *B. bassiana* in the environment, contributing to the biological control of *M. armatus.*

The levels of pathogenicity, virulence, and persistence of beneficial EPF in fields are strongly influenced by various negative abiotic effects, such as temperature and soil pH, moisture and texture, as well as their distribution and abundance (Fisher et al., 2011; Dong et al., 2016; Li et al., 2014). Thus, to achieve acceptable efficacy of EPF strains for the control of pests in field conditions, they must have high virulence and specificity for the target species as well as tolerance to abiotic factors (sunlight, temperature, and relative humidity, among others).

This is the first study to evaluate the efficiency of microbiological and chemical insecticides against *M. armatus*. The integrated management of this pest is very important since fipronil, ethiprole, and chlorpyrifos are still used as standard treatments to manage pests. Our results show that Bometil, Ballvéria, and Acera are promising microbiological products for use against *M. armatus* adults infesting soybean crops.

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