Topics in

Agricultural Entomology XIII

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Outros organizadores
Edimar Peterlini
Érica Ayumi Taguti
João Rafael Silva Soares
Matheus Cardoso de Castro
Sandy Sousa Fonsêca
Vinicius Ferraz Nascimento
Ricardo Antonio Polanczyk

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Telefone: +55 (42) 3323-5493
www.atenaeditora.com.br
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PREFACE

The Graduate Program in Agronomy (Agricultural Entomology) at the UNESP Faculty of Agricultural and Veterinary Sciences in Jaboticabal has always been characterized by its focus on Integrated Pest Management (IPM). Since its foundation, the program has graduated 287 students with a master's degree and 148 Ph.D. students. They are now active in various areas of the public or private sector and contribute to agriculture's economic and environmental sustainability.

This e-book entitled "Topics in Agricultural Entomology - XIII" was made possible through the immense effort of the Organizing Committee, formed by MSc and Ph.D. students from all research areas of our Graduate Program. In its 14 chapters, readers will find information on the most diverse areas of IPM, with a richness of information on both the fundamental and applied aspects of IPM.

As coordinator of the 2022 edition of the Winter Workshop on Agricultural Entomology, it is my pleasure to provide event attendees with an e-book of excellent content, demonstrating the importance of our research to society.

Prof. Ricardo Antônio Polanczyk

FCAV/UNESP

PPG Entomologia Agrícola Coordinator

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SELECTIVITY OF INSECTICIDES AND BIOINSECTICIDES TO COMMERCIALLY USED PARASITOIDS OF *Diatraea saccharalis* ON SUGARCANE

Érica Ayumi Taguti

Gabriel Gonçalves Monteiro

Ivana Lemos Souza

Nilza Maria Martinelli

1 I INTRODUCTION

Brazil is considered the world's largest producer of sugarcane, *Saccharum* spp. (Poales: Poaceae), with a production of approximately 654.8 million tons and 8.62 million hectares of harvested area in the 2020/2021 growing season, representing an increase of 1.8 and 2.1%, respectively, relative to the previous year (CONAB, 2021).

This high production can be affected by the infestation of pests such as *Diatraea saccharalis* (Lepidoptera: Crambidae), *Hyponeuma taltula* (Lepidoptera: Noctuidae), *Mahanarva fimbriolata* (Hemiptera: Cercopidae), *Sphenophorus levis* (Coleoptera: Curculionidae), *Migdolus fryanus* (Coleoptera: Vesperidae), *Aclerda takahashii* (Hemiptera: Aclerdidae), *Saccharicoccus sacchari* (Hemiptera: Pseudococcidae), *Telchin licus* (Lepidoptera: Castniidae), and *Heterotermes tenuis* (Isoptera: Rhinotermitidae), with *D. saccharalis* being one of the main pests of the crop (Machado; Habib, 2006; Zenker et al., 2007; Dinardo-Miranda et al., 2007, 2012, 2013a; Pavlu & Molin, 2016; Monteiro; Peronti & Martinelli, 2022).

The sugarcane borer, *D. saccharalis*, causes direct damage in its larval stage such as the opening of galleries and causes the death of buds, generating great losses in production and low sugarcane quality. Thus, the insect requires efficient control measures for population reduction (Botelho & Monteiro, 2011; Dinardo-Miranda et al., 2013b).

Among these measures, integrated pest management (IPM) should be used to reduce the population of insect pests (Van Lenteren et al., 2018). According to Kogan (1998), IPM is the decision-making about which control strategies will be used, together or separately, considering the cost-benefit and social and environmental impacts. IPM uses chemical and biological control. The biological considers the macrobiological (parasitoids and predators) and microbiological (viruses, bacteria, fungi, and nematodes) (Van Lenteren et al., 2018; Marrone, 2019).

One of the alternatives in biological control is the use of natural enemies, especially *Cotesia flavipes* (Hymenoptera: Braconidae) and *Trichogramma galloi* (Hymenoptera: Trichogrammatidae) to control the sugarcane borer *D. saccharalis* at two different stages of development. The parasitoid *C. flavipes* acts while the sugarcane borer is at the larval stage and *T. galloi* acts in the eggs, that is, preventing the sugarcane borer from developing and completing its cycle (Vacari et al., 2012; Parra; & Coelho Junior., 2019; Kassab et al., 2020). These natural enemies can be used alone or associated (Botelho et al., 1999).

Another method of biological control is based on entomopathogenic fungi, which represent a total of 80% in Brazil, especially *Metarhizium anisopliae* and *Beauveria bassiana* (Ascomycota: Hypocreales) (Mascarin et al., 2019). Both are used in sugarcane mills to control the sugarcane borer and other pests that attack the crop, such as leafhoppers. Their use has increased by 20% annually (Destéfano et al., 2004; Van Lenteren et al., 2018), showing to be important in IPM due to their selectivity, specificity, efficiency, low toxicity to natural enemies, and causing little environmental impact (Lacey et al., 2015).

Insecticides used for chemical control in sugarcane cultivation can affect the action of other organisms, such as entomopathogenic fungi and natural enemies, causing toxicity (Botelho & Monteiro, 2011). In many cases, chemical control is applied with biological control, making it essential to use selective products that act on insect pests and not on natural enemies (Degrande et al., 2002).

There are some methods to assess the selectivity of insecticides to natural enemies for these products, such as spraying the eggs before offering them to the parasitoid, spraying the eggs after offering them to the parasitoid, direct contact with surfaces containing the product, or transgenerational generation, which is the female's ability to hatch from treated eggs (Foerster, 2002).

Selectivity is the ability of a product to control the target pest without causing impacts on natural enemies, thus allowing its survival and reproduction, both in the same environment (Foerster, 2002). Different from selectivity, specificity is related to the variety of hosts that a parasitoid can attack, which can be generalists when using a large number of host species and different taxa, or specialists, when they have few host species, for instance, *T. galloi* (Querino & Zucchi, 2012; Laumann & Sampaio, 2020).

Selectivity of products is important in sugarcane, allowing knowing its correct property and formulation to control the insect pest, associated to the correct form of application, cultivation conditions, and the environment of the target pest (Foerster, 2002), without affecting the natural enemies present.

2 I METHODS TO ASSESS SELECTIVITY

The International Organization for Biological Control (IOBC) coordinates international activities and standardizes selectivity methods to form a database with various information to show which products to use in IPM. For this, test protocols were developed, including laboratory, semi-field, and field tests (Hassan et al, 1994).

Many selectivity studies have been carried out with egg parasitoids to assess their potential, such as *T. galloi* to control *D. saccharalis* (Parra & Zucchi, 2004). Some methods can be used for this purpose, such as:

2.1 Pre-parasitism spraying

Diatraea saccharalis eggs are sprayed/immersed in the product and then offered to *T. galloi*, then checking whether the eggs have been parasitized (Goulart et al., 2008; Potrich et al., 2009; Taguti, 2021).

2.2 Post-parasitism spraying

Diatraea saccharalis eggs are offered to the parasitoid *T. galloi* and then sprayed/immersed in the product, observing the emergence and longevity of the parasitoid (Potrich et al., 2009).

2.3 Exposure to treated surfaces

The product is applied to the plant or glass surfaces and, after drying, *T. galloi* is placed in contact with the contaminated surface and its survival is evaluated (Taguti, 2021).

2.4 Transgenerational effect

The caterpillar of *D. saccharalis* is contaminated with the product and follows its phase until the formation of a couple and oviposition. The eggs from the contaminated female are offered to *T. galloi* and, subsequently, assessed whether or not were parasitized and if the parasitoid will develop (Costa et al., 2014; Santos, 2021).

3 | PARASITOIDS USED IN SUGARCANE

3.1 Cotesia flavipes

Cotesia flavipes is a parasitoid native to the Indo-Australian plate, belonging to the eastern and Australian zoogeographic regions (Overholt et al., 1997). The wasp parasitizes different species of caterpillars of the families Crambidae, Noctuidae, and Pyralidae (Lepidoptera), which feed on plant tissues of Cyperaceae, Poaceae, and Typhaceae (Poales) plants (Overholt et al., 1997; Fujie et al., 2018).

The insect, dispersed worldwide, was introduced in Brazil in the 1970s from specimens from Trinidad and Tobago to control the sugarcane borer *D. saccharalis* and is currently used in 3.5 million hectares to control this pest (Pinto et al., 2022). In sugarcane, there is also a record of parasitism of the braconid on the sugarcane borer *Diatraea flavipennella* (Lepidoptera: Crambidae) (Barbosa et al., 2020).

Adult females of the insect, which are approximately four millimeters long, lay approximately 40 eggs in the host's body cavity (Fujie et al., 2018; Pinto et al., 2022). The larvae start feeding the hemolymph, the host's body fluids, after three or four days (Barbosa et al., 2020; Pinto et al., 2022). The larvae, which have passed through three instars, leave the host's body at approximately 14 days to weave a cocoon and become a pupa, which will be located within the plant tissues of the host plant of the pest organism (Barbosa et al., 2020; Pinto et al., 2022). The adult will emerge within six days (Overholt et al., 1997; Fujie et al., 2018; Barbosa et al., 2020; Pinto et al., 2022).

3.2 Trichogramma spp.

There are more than 210 *Trichogramma* spp. parasitoids distributed worldwide, of which 28 occur in South America and all of them in Brazil (Pinto, 2006). These parasitoids, some of unknown origin, are mostly from the Nearctic zoogeographic region, native to the United States and Mexico, such as the species *Trichogramma pretiosum* and *T. galloi* (Hymenoptera: Trichogrammatidae) (Zucchi & Monteiro, 1997). This group of wasps parasitizes eggs of insects of the orders Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, and Thysanoptera, which are present in several crops (Monnerat et al., 2007; Dalvi et al., 2014; Amaro et al., 2015).

The control of sugarcane pest insects by the parasitism of *D. saccharalis* eggs, using trichogrammatids, began in 1925 in Louisiana, the United States of America, and Barbados (Hinds & Spence, 1929). In Brazil, the first releases of wasps occurred in 1983 in the sugarcane crop in the states of Sergipe and Rio de Janeiro (Querino & Zucchi, 2002). Wasps are released annually in more than four million hectares of sugarcane to control sugarcane pests. In addition to the sugarcane borer *D. saccharalis* and *D. flavipennella*, there is a record of parasitism of the cotton leafworm *Alabama argillacea* (Lepidoptera: Noctuidae) eggs by *T. galloi* (Zucchi et al., 2010).

Adult females lay their eggs in eggs of insects of the orders Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, and Thysanoptera (Monnerat et al., 2007; Dalvi et al., 2014; Amaro et al., 2015). The characteristic of a parasitized egg is its darkening (Dalvi et al., 2014; Valente et al., 2016). The larva inside the egg will go through three instars and adults emerge from the pupa and leave the parasitized egg at the end of the cycle (Milanez et al., 2018). Two to three adult individuals come from each egg (Oliveira et al., 2017).

4 I INSECTICIDES AND BIOINSECTICIDES USED IN SUGARCANE

Integrated pest management (IPM) is one of the most concise ways to control the sugarcane borer, using mainly biological and cultural control and resistant varieties. Chemical control is also used in more challenging cases (Cruz, 2007) due to the habit of the larval stage of the borer to remain inside the stalk, which makes its reach more difficult through insecticides. Thus, insecticides should be applied when the larvae are in the 1st and 2nd instar, before entering the stalk (Matioli, 2019).

Control methods must be used concomitantly as an IPM premise to better act in pest control (Van Lenteren et al., 2018). Thus, special attention should be given to the strategy of associated methods, such as biological and chemical controls, due to the presence of the insecticide, which may negatively influence parasitoid performance. A total of 53 insecticides are registered for sugarcane to control sugarcane borer, among them ten active ingredients (chlorantraniliprole, chlorfluazuron, diflubenzuron, fipronil, flubendiamide, lufenuron, novaluron, tebufenozide, teflubenzuron and triflumuron) and three insecticides derived from the association of two active ingredients (chlorantraniliprole + lambda-cyhalothrin, lambda-cyhalothrin + thiamethoxam and methoxyfenozide + spinetoram), belonging to eight chemical groups (MAPA, 2022).

5 I SELECTIVITY OF PHYTOSANITARY PRODUCTS TO SUGARCANE PARASITOIDS

The selectivity of phytosanitary products to natural enemies, such as parasitoids of agricultural pests, is the one that selects a product that poses a low risk to the agricultural environment (Gazzoni, 1994). In other words, it is the use of a product that targets the pest and does not affect the pest parasitoid, soil, and water.

Methods that assess selectivity can often classify whether the product is suitable or not to be used safely against natural enemies (Benvenga et al., 2016). Some studies have investigated the selectivity of insecticides and parasitoids. These studies are based on different aspects, some of them evaluated through applications to the host and subsequent evaluation in the parasitoid, and others by residual contact in leaves; both can affect the parasitoid performance and its biological parameters (Antigo et al., 2013; Costa et al., 2014; Fonseca et al., 2015; Matioli et al., 2019).

Matioli et al. (2019) tested seven insecticides used to control the sugarcane borer. Chlorantraniliprole + lambda-cyhalothrin and lambda-cyhalothrin + thiamethoxam led to 100% mortality to the parasitoid *C. flavipes* in direct contact with leaf discs of sugarcane, being classified as harmful. However, chlorantraniliprole, chlorfluazuron, triflumuron and novaluron were harmless to the parasitoid, with mortality lower than 25%, while tebufenozide was completely harmless.

Parasitoids evaluated by residual contact left by insecticides were investigated; unlike triflumuron, fipronil negatively affected survival, longevity, and growth of *C. flavipes*. *Cotesia flavipes* successfully parasitized larvae fed diets treated with lufenuron, but delayed biological development was observed (Fonseca et al., 2015).

Eggs parasitized by *T. galloi* were submerged in insecticide solutions: tebufenozide did not affect the development (egg to pupa) of *T. galloi*, but lufenuron showed high toxicity. Likewise, these eggs submerged before being parasitized had the same results. Both insecticides did not affect parasitism, but lufenuron reduced adult emergence (Cônsoli et al., 2001). In addition to these insecticides, parasitized eggs sprayed with fipronil, triflumuron, and lambda-cyhalothrin + thiamethoxam caused negative effects on the egg, larva, pre-pupal, and pupal stages of the parasitoid *T. galloi* (Costa et al., 2014).

Importantly, several insecticides are available in the agricultural market to control the sugarcane borer, and, among them, there are those that, in addition to control, are also compatible with other forms of control. Studies carried out on the selectivity of parasitoids used in the sugarcane crop have shown that the insecticides chlorantraniliprole, chlorfluazuron, triflumuron and novaluron have low mortality for *C. flavipes* and tebufenozide is totally innocuous for *C. flavipes* and *T. galloi*.

Among the bioinsecticides used to control sugarcane pests, those based on the entomopathogenic fungi *B. bassiana* and *M. anisopliae* have been used to control the sugarcane borer and other pests, such as *M. fimbriolata* (Destéfano et al., 2004).

According to Rossoni et al. (2014), the fungi *B. bassiana* (IBCB 66 and ESALQ PL63) and *M. anisopliae* (PL43, IBCB 425, and E9) demonstrate selectivity to females of *C. flavipes*. Similarly, Santos et al. (2022) observed that *B. bassiana* (IBCB 425) and *M. anisopliae* (IBCB 66) are compatible and safe for *C. flavipes* and Hayashida et al. (2012) observed that *M. anisopliae* (UFGD 05, IBCB 348, and IBCB 425) was selective for this parasitoid.

The parasitism rate, emergence, and longevity of *T. galloi* were reduced when postures were immersed in a bioinsecticide solution with three different strains of *M. anisopliae* (IPA159E). The strains (IPA 211 and IPA 139E) did not affect the parasitism and only *M. anisopliae* (IPA 211) affected the emergence rate and longevity (Broglio-Micheletti et al., 2006).

Taguti (2021) evaluated *B. bassiana* and *M. anisopliae* in adults of *T. galloi* and eggs of the host *D. saccharalis* parasitized before and after. *Metarhizium anisopliae* and *B.*

bassiana did not affect the parasitism rate, emergence rate, and longevity of the parasitoid. On the other hand, *M. anisopliae* stood out with a higher parasitism rate relative to the fungus *B. bassiana* (Santos, 2021).

The compatibility between chemical and biological control agents present obstacles to be investigated and certainly solved. However, these relationships become more complex because they influence another controlling agent, the parasitoids (Santos, 2021). This interaction can often harm in some way, affecting biological parameters and even affecting the behavior of parasitoids, repelling or attracting them (Smaniotto et al., 2013; Luckman et al., 2014). Therefore, *B. bassiana* and *M. anisopliae* showed selectivity to *C. flavipes* and *T. galloi*.

6 | FINAL CONSIDERATIONS

Several authors have studied the selectivity of pesticides to natural enemies, but few studies have been dedicated to exploring the selectivity to hymenopteran parasitoids used for the biological control of sugarcane pests. Therefore, studies focused on this area are important to clarify information on the joint use of chemical and biological controls, so that there is no depreciation of the efficiency of the used parasitoids.

These control methods should be used together with other control methods as a premise of IPM to promote higher efficiency on the pests, which cause economic losses to sugarcane fields. Further studies on the use of biological and chemical controls are required. There is no information on other parasitoids and insecticides that can be used in the sugarcane crop. Moreover, the information on *T. galloi* and insecticides is scarcer than information to *C. flavipes* even though the braconid has been used commercially for more time for the sugarcane borer than the trichogrammatid (Botelho, 1992). The sugarcane market is quite innovative and technological. Thus, it is interesting that the focus of new studies is always on the selectivity of insecticides together with bioinsecticides, showing all parasitoids that can be used to control pests in the sugarcane crop.

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