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BIOLOGICAL CONTROL OF PESTS AS A KEY COMPONENT FOR SUSTAINABLE SUGARCANE PRODUCTION

José Roberto Postali Parra, Paulo Sérgio Machado Botelho and *Alexandre de Sene Pinto*

INTRODUCTION

Although Brazil is the leading producer of sugar and alcohol in the world, with a production of 31.3 mm tons of sugar and 27.7 mm cubic meters of ethanol in 2008/2009 (MAPA, 2009), these values could be still higher if it wasn't for insect pest attack on different parts of the cane plant, including seed pieces or setts, roots, stalk base, stalk and leaves, causing significant losses in yield.

Various cane pests are dealt with in books (GUAGLIUMI, 1972/1973; MENDONÇA, 1996), with GALLO *et al*. (2002) describing 24 of the most important species in Brazil.

It is interesting to point out that although there are regional peculiarities, the main pests are controlled by biological alternatives, whether by insects or pathogens (ALVES; LOPES, 2008; PARRA *et al*., 2002). Therefore, sugarcane is one of the few crops in Brazil where sustainability has been practiced since the 1970s (GALLO, 1980).

Biological control (BC) is intensively used to control the main pests, including the sugarcane borer, *Diatraea saccharalis*, principally in the Southeast and the froghopper, *Mahanarva posticata*, in Northeast Brazil. In the case of the sugarcane borer, an imported parasitoid, *Cotesia flavipes,* is used, which is currently liberated in around 1,700,000 hectares through one of the most unique BC programs in the world (POTTING, 1996) due to its efficiency and the area covered (PARRA, 2008, personal communication).

Similarly, biological control has been used for the control of froghoppers for many years, including the leaf froghopper, *M. posticata,* in the Northeast. Today in Brazil, the green muscardine fungus, *Metarhizium anisopliae*, is applied on around 1 million hectares to control the root froghopper, *M. fimbriolata*, a recent problem in sugarcane in the Southeast (ALVES; LOPES, 2008).

Therefore, with the perspectives of a doubling of the area planted with sugarcane in the near future, there is a worry that with the opening up of new areas, sustainable crop production will not be respected and chemical products (particularly by aerial spraying) will be applied indiscriminately. This may cause disastrous secondary outbreaks and the appearance of "new pests" which would make the maintenance of those measures adopted almost 50 years ago more difficult.

The objective of the present paper is to show the perspectives for using BC to control the main pests in modern sugarcane production; and what research needs to be done so that alternative control measures become a key component for producing sustainable sugarcane.

FACTORS WHICH CAN ALTER THE SUGARCANE ENTOMOFAUNA

Harvesting

The "raw cane", that is, cane harvested mechanically without being burnt beforehand, is a reality today, but despite the environmental advantages of this practice it does alter the plant micro-climate and favor certain pests. This is the case of the root froghopper, *M. frimbriolata*, which, together with the sugarcane borer, *D.*

saccharalis, are the most important pests in São Paulo state (MENDONÇA, 2005; GARCIA *et al*., 2006; 2007a, b). The same thing occurs with the sugarcane weevil, *Sphenophorus levis*, studied since the 1980s (DEGASPARI *et al*., 1987) and which had been restricted to the Piracicaba region until a short time ago, but currently can be found in a 100 towns in São Paulo and even extends into Minas Gerais state.

The problem caused by *S. levis* increases in areas which are harvested mechanically due to the increase in cane trash deposited on the soil, increasing the availability of shelter for the insect and making its control difficult. On the other hand, such conditions can favor microbial control. However, in the light of present knowledge, control of this pest is very difficult (PINTO *et al*., 2006). Nests of leaf-cutting ants are also more difficult to locate where cane trash is deposited on the soil surface.

Quarantine problems

The exchange of seedlings can result in the appearance of new problems. This occurred recently with the registration of *Telchin licus* in São Paulo. This insect, known as the giant sugarcane borer, was restricted to the Northeastern states and limited by the river São Francisco. Observed in June-July 2007 in São Paulo, it will probably become a significant problem due to its size, long life cycle, the damage it causes and by the absence of any control measures.

Secondary outbreaks

The systematic application of certain chemical products to control leaf-cutting ants (*Atta* spp.) and even other foliage pests, has killed off predators, especially ants, so that pests which were not a problem have become one. An example is *Hyponeuma taltula*, the hairy borer, which is already considered the main pest in some regions of Brazil. The population levels of other common caterpillars in sugarcane, such as *Spodoptera frugiperda*, *Pseudaletia sequax* etc., are able to increase and cause considerable damage in such secondary outbreaks.

Cultivation systems

In no-till situations, the burrower bug, *Scaptocoris* spp., has increased its importance, aggravated by the fact that there are no efficient control methods for this subterranean pest (FERNANDES *et al*., 2004).

Soil characteristics

Pests such as subterranean termites (especially *Heterotermes tenuis*), the lesser cornstalk borer, *Elasmopalpus lignosellus* (VIANA, 2004) and *Migdolus fryanus* (BENTO *et al*., 1995) occur more in sandy soils.

The problems with subterranean termites increased after the prohibition of organochlorine products, which were applied together with fertilizers at planting, and today, these termites are controlled almost exclusively with modern synthetic chemicals whose residues are still little studied.

E. lignosellus is more important in areas with sandy soils and in the savannah regions ("cerrados"), occurring mainly in dry-climate years or when there are summer droughts. It occurs less in areas of "raw cane".

M. fryanus, which is present in 100,000 hectares in São Paulo state, has a unique biology and is principally controlled with insecticides, which means the application of a quantity of agrochemicals which is incompatible with environmental conservation and sustainability. This situation should drive the development of research for changes in control.

DAMAGE CAUSED

The damage caused has only been quantified for some pests. Many of them, such as *T. licus*, *S. levis*, and *M. fryanus*, can, when they occur, cause significant damage although such damage has, in general, not been quantified up to now.

Sugarcane borer, *D. saccharalis*

The sugarcane borer is the pest for which there is most bioecological information in sugarcane (PARRA *et al*., 1988; MÉLO; PARRA, 1988;

PARRA; MIHSFELDT, 1992; PARRA, 1993; PARRA *et al*., 1999).

Since the 1950s, there has been an exhaustive series of similar types of studies on the damage caused and it was concluded that, on average, the sugarcane borer caused considerable damage: each 1% infestation resulted in losses of 0.42% of sugar or 0.21% of alcohol and a 1.14% weight loss.

The damage is greater in plant cane, which grows more vigorously, independent of the variety. The soil preparation for plant cane also eliminates the natural enemies which maintain the pest population in equilibrium (BOTELHO; MACEDO, 2002).

Damage can be direct (dead vascular tissue, aerial rooting, lateral shoots, weight loss, stem breakage) and indirect (caused by the fungi *Colletotrichum falcatum* and *Fusarium moniliforme*). The red-rot, in the case of indirect damage, inverts the sucrose level thereby lowering sugar production and the fungi and other microorganisms compete with the yeasts in the fermentation of the alcohol.

There have been times, such as in the 1980s, when infestations reached 10% in São Paulo state, with yearly losses of US$ 100 mm due to pest attack.Today, with new varieties which are richer in sucrose, an increase in planted area and an inadequate control of the pest, the mean infestation level may reach higher levels than those registered in the 1980s, if there is no investment in the production of beneficial and the training of labor to implement the correct field control measures.

Froghopper

Leaf froghopper, Mahanarva posticata

The adults suck sap from those cells on the periphery of the parenchyma and reduce photosynthesis. As a consequence of this constant sucking, maturation is delayed, the internodes are atrophied and there is a reduction in stem sucrose which affects the quality of the juice and agricultural and industrial yields.

The adults are toxigenic and on introducing the toxins, formed by a complex of enzymes and oxidizing amino acids, cause alterations in the cellular tissue of the area affected. The extent of the chlorosis causing the leaf "burning" depends on the number of "bites" and the physiological state of the sugarcane. The nymphs perforate and contaminate the roots, which stops water and nutrient uptake and causes the plant to produce new roots. They cause plant malnutrition and dehydration during the rainy period (when froghoppers occur). This continuous sucking by nymphs can result in the same damage caused by the adults. The damage caused by nymphs and adults in big infestations can cause yield losses of 17% in sugar production in the Brazil's Northeastern region.

Root froghopper, Mahanarva fimbriolata

Research on this pest has been facilitated by recent studies on its biology, fertility life table and breeding techniques by GARCIA *et al*. (2006) and GARCIA *et al*. (2007b).

The adults cause a "burning" of the sugarcane on injecting the toxins into the leaves and also reduce plant photosynthesis. The nymphs cause a "physiological disturbance" due to the bites which affect the root tracheae, resulting in their deterioration and making the water and nutrient flow more difficult due to the dehydration of the phloem and xylem. They insert the stylets into the epidermis, which pass through the cortex and reach the vascular cylinder, feeding on the contents of the perforated tube of the primary phloem. The adults of *M. fimbriolata*, introduce their stylets through the stomata, pass through the cells of the chlorophyllous parenchyma and reach the metaxylem in the vascular bundles (GARCIA *et al*., 2007a). Also, similar to that which occurs with *M. posticata*, as a consequence of the constant sucking of sap, there is a reduction in sucrose levels in the stalk which affects juice quality and industrial and agricultural yields (MADALENO *et al*., 2008).

The dehydration of the phloem and xylem can result in a hollow stem, with the appearance of external wrinkles. Tillers can die and lateral shoots may appear which changes the plant architecture so it looks like a palm tree.

The damage in areas of raw cane where the pest is a problem can be as high as 11% of the agricultural productivity with a 1.5% reduction in sugar levels.

Damage is greater in ratoon cane and the second generation of the pest (there are two or three generations) can reduce productivity by up to 26% (GARCIA *et al.*, 2006). General aspects, including the effect of varieties and of harvest timing on infestation levels, have been discussed by DINARDO-MIRANDA *et al.* (2001).

Termites

There are various genera of subterranean termites which attack sugarcane (*Heterotermes*, *Procornitermes*, *Neocapritermes* and *Syntermes*). However, the most important genus is *Heterotermes* with *H. tenuis* causing the most damage. This species has a tapering body, is milky white, with a yellowish cephalic capsule, a thorax with rounded sides and long mandibles. It does not take back any soil to the galleries it builds inside the stalks like other species, such as *Procornitermes*, do. Its nests are subterranean, concentrated and underground, shaped like cylinders, about 10 cm high and 6cm in diameter, completely closed except for the two extremities which communicate through galleries. In order to feed (cellulose), the termites attack plants growing near their nests.

The termites attack seed pieces, damaging the buds and affecting germination, causing gaps in the stand which often have to be replanted. Yearly losses can reach 10 tons/ha and the termites are more commonly found in sandy soils (VALÉRIO *et al.*, 2004).

Other pests

There are other less common pests whose attacks can cause a total loss although there are no evaluations (studies) on this for São Paulo state or for Brazil. This is the case for *M. fryanus*, *T. licus*, *S. levis*, *Scaptocoris* spp. and *H. taltula*. However, their occurrence is more restricted, except for *T. licus*, whose distribution and damage potential are still unknown due to its recent introduction into São Paulo state. This pest may cause losses similar to those of the sugarcane borer, *D. saccharalis*, in the Northeast, although the caterpillar's much larger size could result in greater damage. In areas infested by *S. levis*, 50% to 60% of the tillers are attacked, resulting in losses of 20 to 30 tons per hectare (PINTO *et al.*, 2006).

Other pests, such as the aphids *Rhopalosiphum maidis* and *Melanaphis sacchari* associated with sugarcane mosaic virus and sugarcane yellow leaf virus respectively, have been controlled by using resistant varieties. White grubs are controlled at the same time as the termites.

CONTROL ALTERNATIVES

Diatraea saccharalis

The sugarcane borer has been controlled since the 1970s by the imported parasitoid, *Cotesia flavipes*. This parasitoid has been studied extensively together with the sugarcane borer (BOTELHO; MACEDO, 2002; PÁDUA *et al.*, 1994).

Around 6,000 parasitoids are liberated per hectare at a cost of US$ 7/ha. At the present time, with the appearance of private companies selling such agents (there are about 20 firms selling this parasitoid in Brazil) and with the reactivation of laboratories in the mills with large scale production, parasitoids are liberated on around 1.7 mm hectares (PARRA, 2008, personal communication). The success of this program, one of the biggest in the world due to the area treated, is demonstrated by the reduction in losses caused by the borer: these used to reach US$ 100 mm a year in São Paulo state in the 1980s, and are now US$ 20mm in areas where liberations have been made. General aspects of the production and liberation of the parasitoid are described in MACEDO and BOTELHO (2002).

A new alternative exists today for controlling this pest in sugarcane: the egg parasitoid, *Trichogramma galloi*, produced by two firms in Brazil (PARRA, 2008, personal communication).

Since the key factor in the population growth of *D. saccharalis* is the egg stage (BOTELHO, 1985), it is expected that this parasitoid will efficiently control this pest. Research results have shown that when around 200,000 *T. galloi* parasitoids are liberated per hectare, at weekly intervals, in three liberations, and associated at the same time with *C. flavipes*, infestation intensity was reduced by up to 60% (BOTELHO *et al*., 1999).

The parasitoid *T. galloi*, which has already been liberated on 150,000 hectares, should be liberated in preference to *C. flavipes* where the latter is inefficient or in areas where egg predation is low.

Biological control of *D. saccharalis* by *C. flavipes* is efficient as long as the pest infestation level is not greater than 3% and by *T. galloi,* when the first *Diatraea* eggs appear in the crop, generally 50 to 60 days after planting of the sugarcane (LOPES, 1988). There have been many studies over the last few years on the parasitoid (PARRA; SALES JR., 1994; BOTELHO *et al*., 1995a, b; 1999; CÔNSOLI *et al*., 2001; PINTO *et al*., 2003; PARRA; ZUCCHI, 2004).

Froghoppers

Although there are varietal differences, with some varieties, such as SP 79-1011, suffering less attack by the root froghopper in São Paulo state, plant resistance is still not a viable control alternative. The total elimination of cane trash by mills, which could reduce future froghopper populations, is also not economically viable.

Other biological agents such as egg parasitoids (*Anagrus urichi* and *Acmopolynema hervali*) and predators such as *Salpingogaster nigra,* occur naturally but are difficult to handle in the laboratory, which makes their manipulation difficult. They should be preserved by avoiding agrochemical applications in the crop.

The economic threshold level for the root froghopper is two nymphs per linear meter of row. The sampling is done at five points per hectare, with each point represented by a linear meter of row. The sampling should be done with the first pest generation when the rains begin.

The green muscadine fungus, *M. anisopliae*, currently produced and sold by ten firms, has been used to control both species in the Northeast since the 1970s and is presently applied on about 1 mm hectares.

The quality of the fungus, its dosage and formulation (wettable powder, granules or oil-based) are the key to successful control. It should be applied at high volumes (300 liters of water) at a concentration of 5 x 10^{12} viable conidia per hectare, the equivalent of 225 g of pure conidia or five kilos of fungus plus culture medium (rice). Since this pathogen needs certain temperature and humidity conditions, efficiency will be greater if applications are made at dusk since, besides avoiding the action of UV light, which degrades the fungus, it permits the germination of the conidia under these same environmental conditions.

Since there is a close correlation between froghopper populations and excess soil water, the time when the pest occurs also favours fungal development.

Termites

Although termites are controlled chemically, their control should not be over the total area in order to avoid greater outbreaks.

In reformed areas, examine 20 rootstocks per hectare to evaluate the presence of termites. Another option is the use of corrugated cardboard baits (Termitrap®), using 20 baits per hectare. The economic threshold level is 25% infestation.

In ratoon cane, use Termitrap® type baits which contain the active ingredient, imidacloprid, together with *Beauveria bassiana* fungus, using 40 baits per hectare per year. This treatment aims nests elimination (ALMEIDA; ALVES, 1996; ALMEIDA; ALVES, 1999).

Migdolus fryanus

There is a sex pheromone of the amide group for this pest, which is restricted to certain areas of Brazil (DIAS FILHO, 1984), and it is sold as one milligram pellets. It can be used for monitoring, with one trap per area of 10 to 20 hectares between October and March, with substitution of the pellets every three or four weeks (BENTO *et al*., 1992; BENTO *et al*., 1993; LEAL *et al*., 1994; BENTO *et al*., 2004). However, the control of this pest is mainly with insecticides. Mechanical control during plantation reform, to reduce larval populations which are feeding at the rootstock base, is extremely efficient when done at the right time.

Photos: Negri.

FIGURE 1 Most common biological agents used to control sugarcane pests. A. *Cotesia flavipes* parasitizing a caterpillar of *Diatraea saccharalis*; B. *Trichogramma galloi* on eggs of *D. saccharalis*, where b_1 is a normal oviposition of the sugarcane borer and b_2, one parasitized by the microhymenopteran; C. Nymph of *Mahanarva fimbriolata* infected by the green muscardine fungus *Metarhizium anisopliae*, also showing healthy adults of *M. posticata* (c_1) and *M. fimbriolata* (c_2).

PROPOSALS FOR DEVELOPING SUSTAINABILITY IN SUGARCANE

Although sugarcane is one of the crops where biological control is most practiced in Brazil, based on the "Technological Workshop on Sugarcane Pests" held in Piracicaba, São Paulo state, in August 2007, it is possible to define actions to develop control alternatives, especially pest biological control, as a key component for sustainable sugarcane production.

These actions may be summarized as follows:

- In general terms, it can be concluded that critical mass is desperately lacking in the area of sugarcane pests and this calls for training, whether it be of researchers or technicians.
- On the other hand, there is a lack of equipment and better-organized laboratories, to enable Brazil to be on an equal footing with laboratories in the developed countries where the synthesis of semio-chemicals, or even volatile plant substances, are routine activities. Only through training and equipping such laboratories will Brazil be able to reduce its dependence on outside help.
- Another aspect discussed, and which merits reflection, is that the projects (or research) are isolated, as is usually the case in our work, with no inter or multi-disciplinary actions to produce global results instead of just local ones.
- The giant sugarcane borer, *T. licus*, recently introduced into São Paulo state, should merit special attention due to the damage it causes and what it could represent for the sugarcane crop with the large predicted expansion in planted area. Bioecological studies of the pest, monitoring methods and control alternatives should be extensively researched since the control methods presently in use are empirical and inefficient.

Soil pests

- Studies should be made relating the effect of cane trash and decomposing species on the new agroecosystem resulting from mechanical harvesting and also the effects on soil pests, beneficials and entomopathogens;
- Alternatives for the control of *E. lignosellus*, *S. levis*, *H. taltula* etc.;
- Environmental impact of chemical control on important soil species;
- Relationship between population density and the damage caused (with emphasis on the root froghopper, *M. fimbriolata*);
- Evaluation of the efficiency of biological control on pests (biological and microbial control should be favored by mechanical harvesting);
- Bioecological studies of traditional and secondary pests (which could become primary pests);
- Monitoring and sampling techniques for soil pests.

Biological and chemical control

- Pest monitoring studies (including geoprocessing) to sample them adequately and control them rationally, whether it be through biological or chemical options.
- Determination of the economic threshold levels of the more important pests (for different control options).
- Environmental impact studies of agrochemicals and control alternatives in the agroecosystem (selectivity, niche occupation, biological outbreaks, pest resurgence, resistance management).
- Bioecological studies of primary and secondary pests.
- Production methods for parasitoids, predators and entomopathogens.
- Quality control of beneficials and pathogens produced in the laboratory.
- Search and identification of new biological control agents, involving studies on disease epizootiology, pest population dynamics, strain selection and of biological control agents.

Transgenic plants and pest control in sugarcane

- Although it is known that transgenic plants will be available to farmers only in the medium and long terms, support should be given to transgenic research currently being done, whether it be with *Bacillus thuringiensis* (Bt) for *D. saccharalis*, or Bt allied to proteinase inhibitors for Coleoptera (*M. fryanus* and *S. levis*) and other possible techniques, aiming at other pests in the crop.
- Studies on the regulation of transgenic plants compatible with Brazil's reality as well as matters linked to intellectual property rights.

Pheromones

- Studies (explanatory campaigns) demonstrating the viability to the farmer of using synthetic pheromones for monitoring and control (*M. fryanus*) and others which might eventually be synthesized and which can substitute the agrochemicals presently in use.
- Research in the short term to synthesize pheromones for *S. levis* and *D. saccharalis*.
- Research in the medium and long terms to develop and synthesize pheromones [for *T. licus*, *E. lignosellus* and white grubs (*Scarabaeidae*)].
- Incentive of entrepreneurship – formation of firms with a technological base for the commercialization of semiochemicals as well as beneficials and entomopathogens.
- As already mentioned, multi – and interdisciplinary programs which would need the development of human resources, the acquisition and maintenance of equipment and facility in buying solvents.

Measures need to be urgently taken because the volume of entomological problems in Brazil will probably increase with the occupation of new areas with sugarcane, having different climatic conditions, as well as the use of new cultivation systems in different soil types and different ecosystems. All these variables together will certainly result in increased entomological problems to be added to those that already exist.

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