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Biological Control in Brazil: state of art and perspectives

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Introduction

Brazil is one of the most extensive users of Biological Control (BC) (including both micro and macroorganisms) in the struggle to control agricultural pests. Nowadays, BC is seen not only as a measure supported by bioagents but also as an approach involving biofertilizers and biostimulants. This is part of a broader view that encompasses bioinputs, defined as agro-industrial products or processes developed from enzymes, extracts (from plants or microorganisms), microorganisms, macroorganisms (invertebrates), secondary metabolites, and semiochemicals (e.g., pheromones), all designated for BC.

Sustainability is the worldwide need of the moment. Achieving this goal is a genuine concern of sustainable agriculture projects which is made possible by, among other measures, using biological products to control pests.

As a leader in tropical agriculture, Brazil must increasingly use BC to meet the requirements of the international markets for agricultural products free from chemical residues.

Entomological pest control involves both micro (fungi, bacteria, virus, nematodes, etc.) and macroorganisms (insects and mites). Although categorized as semiochemicals, pheromones are commonly included in BC, in this case, to monitor or control pests (e.g., the male confusion technique).

In the current philosophy of Integrated Pest Management (IPM), aiming toward sustainability, BC should not be considered in isolation but as a component of IPM, i.e., as a method, similar to other control methods, to maintain pest populations below the economic injury level, which considers economic, ecological, and social criteria.

Biological control: misconceptions and challenges

Although the use of BC has been increasing throughout Brazil, many challenges remain (Parra, 2014). On the other hand, Brazilian producers have met and overcome several obstacles in recent years.

In Brazil, 595 biological products are now registered and available in the market, more than in many countries. One hundred and two new products are registered yearly.

Income reaches 3 billion reais annually (approximately US$ 582 million dollars), with more than 20 million hectares being treated with biological products for crop protection.

Certain misconceptions must be corrected to overcome the remaining challenges of using BC (Parra, 2019). One of these is the cultural bias of farmers who, for generations, have been accustomed to using agrochemicals and insist that this is the only way to control pests. This cultural predisposition began to change in 2013 when sightings of the cotton bollworm *Helicoverpa armigera* (Hübner, 1809) (Lepidoptera: Noctuidae) were recorded in central Brazil. This pest has more than 250 hosts, and at that time, no chemical product was registered to control it. Two biological-control methods were implemented: a virus specific to the larva, and the wasp *Trichogramma pretiosum* Riley, 1869 (Hymenoptera: Trichogrammatidae), already recognized for its excellent control performance in parasitizing the eggs. From then on, local producers have come to have more faith in BC, and this experience was a turning point for this type of control. Eventually, BC began to be used more frequently on several crop species.

Another misconception is that BC methods are easy to use. This leads to amateurish attempts to apply them without the requisite professional consultation. Biological products based on micro or macroorganisms and targeting pest control must be of good quality, regardless of the size and type of facility producing them. Professionalism is essential to preventing the image of BC from being harmed even as its use is increasing.

Nowadays, large companies have portfolios of biological products available and guarantee their quality. Small companies, many startups with few products, should also concern themselves with quality at this critical phase of BC implantation in Brazil. Circa 140 companies now offer registered biological products. For instance, 12 companies are marketing *Trichogramma* spp. (Table 1) Additionally, six offer *Telenomus podisi*, a parasitoid beginning to be used in soybean plantations to control *Euschistus heros* (Fabricius, 1798) (Hemiptera: Pentatomidae) (Parra and Coelho, 2022).

Table 1 – Some pests controlled by species of *Trichogramma* in Brazil (Parra et al., 2015).

Wasp species	Pests	Crop plants
T. galloi	*Diatraea saccharalis*	Sugar cane
T. pretiosum	*Anticarsia gemmatalis* *Chrysodeixis includens* *Helicoverpa armigera*	Soybean
T. pretiosum	*Spodoptera frugiperda* *Helicoverpa zea*	Maize
T. pretiosum	*Alabama argillacea* *Chloridea virescens* *Helicoverpa armigera*	Cotton
T. pretiosum	*Tuta absoluta* *Helicoverpa zea* *Neoleucinodes elegantalis*	Tomato
T. pretiosum	*Lasiothyris luminosa*	Grape vines
T. pretiosum	*Sitotroga cerealella*	Stored grains
T. pretiosum	*Phthorimaea operculella*	Tomato Potato Tobacco
T. pretiosum	*Diaphania* spp.	Melon
T. pretiosum	*Iridopsis panopla*	Forests
*T. atopovirilia** (?)	*Stenoma catenifer*	Avocado
*T. atopovirilia** (?)	*Gymnandrosoma aurantianum*	Citrus

*unregistered species; (?) ongoing studies.

Other misconceptions remain to be clarified. As regards the "cost", for example, BC is still believed to be less expensive than chemicals, without even taking into account the ecological and social advantages. Additionally, BC is (incorrectly) viewed as a long-term control measure that must solve the problem by itself, eschewing the inclusiveness concept of the current philosophy of IPM.

These misconceptions or myths have gradually been exploded. This progress is illustrated by the increase in the use of BC (10-15 % a year worldwide), as against BC use increasing by 30-35 % annually in Brazil.

This increase is also a result of investments by the private sector in the last several years, especially fostered by links between researchers and private companies. Nowadays, even insecticide-producing companies include departments for biological control often treating them as biological inputs.

Brazil has extensive planted areas, with crop succession and two to three harvests per year, much different from regions where BC is traditionally used. In European countries, for instance, the planted areas are smaller, and BC is widely applied in greenhouses. In contrast, Brazil has enormous open fields, with producers owning 20,000, 50,000, or even 100,000 hectares planted for a single crop and only one owner.

Given these characteristics of Brazilian agriculture, we sought to develop a Model of Biological Control for Tropical Regions, as we have already accomplished with agriculture as a whole, becoming leaders in tropical agriculture. Agricultural products comprise much of the Brazilian GDP, as a result of technological advancements over the last 50 years.

Indeed, challenges remain to be overcome to reach this new model which has been the primary goal, especially over the last 30-40 years.

We still face challenges related to the availability of biological control agents, mainly the macroorganisms (in this case, robotics and artificial intelligence have helped with the automation of insect mass rearings), namely, to maintain high quality together with the transfer of technology to the user (extension services are still limited and are a widely unknown subject), an appropriate time for release (control level), as well as logistical, storage, and transport problems for a continent-sized country such as Brazil. The Brazilian continent has an area of 8,514,876 km^2, 29 % greater than the common area of Western European countries, 6,057,203 km^2.

One of the issues described in 2014 (Parra, 2014) was related to the appropriate release of natural enemies. However, this problem has been solved since drones release more than 95 % of natural enemies in sugarcane plantations. The modern entomological application relies extensively on Agriculture 4.0, i.e., precision farming based on automatic data collection and analysis, which is one of the solutions to this challenge. Another two points also helped to overcome this obstacle: sampling for release (which has been thoroughly studied) combined with specific, more discussed, and more agile legislation for BC.

Micro and macroorganisms and prospects for biological control in Brazil

Biological control in Brazil is proceeding well with millions of hectares treated with both microorganisms (about 80 % of the area) and macroorganisms (about 20 % of the area) (Table 2).

What are the reasons for the difference between these two agents? Microorganisms are more similar to chemicals, specifically, in terms of their application. These agents also have a shelf life, at times of a few months. On the other hand, macroorganisms must be used just after they are produced and are often lost in the process. The mass production techniques required to rear millions of insects and mites have begun to be automated since 70-80 % of the production cost is allocated to the labor force. To develop a BC agent for use, several years of investigation are necessary. Sixteen years (1984-2000) were needed to develop the techniques to finally make *Trichogramma galloi*, a parasitoid developed by the research group at the Department of Entomology and Acarology at ESALQ/USP, available to producers. This parasitoid has currently been released over millions of hectares in Brazil.

The inter- and multidisciplinary actions needed in BC range from taxonomic studies to delivery of the product (Parra, 2021). These are related not only to laboratory studies but also to experiments in semi-field and field conditions. These processes involve evaluating

Table 2 – Certain natural enemies utilized in Brazil.

	Species	Area (ha)	Culture
Microorganisms	*Trichoderma spp.*	5 million	Soybean
	Metarhrizium anisopliae	2.5 million	Sugar cane
	Bacillus thuringiensis	1.5 million	Soybean/ Coffee
	Cordyceps fumosorosea	0.3 million	Maize
	Baculovírus	0.3 million	Soybean/ Maize /Cotton
Macroorganisms	*Cotesia flavipes*	3-4 million	Sugar cane
	Trichogramma galloi	3-4 million	Sugar cane
	Trichogramma spp.	0.4 million	Soybean/ Cotton/ Maize/ Vegetables/ Citrus
	Tamarixia radiata	Undefined	Citrus*
	Ageniaspis citricola	Undefined	Citrus*

*Parra et al. (2022)

the best areas to distribute a parasitoid based on its thermal and humidity requirements and relationships to plant phenology to ensure successful results in the field (Figure 1).

The number of professionals with expertise in BC has increased substantially, especially after 60 years of development of postgraduate programs in Brazil. These programs have trained many professionals in this area, together with increases in investment by institutions or centers related to BC including Embrapii (from the Empresa Brasileira de Pesquisa e Inovação Industrial), INCT (Institutos Nacionais de Ciência e Tecnologia) in ESALQ, Bioinputs in Embrapa, and SPARCBio (São Paulo Advanced Research Center for Biological Control) also located at ESALQ and sponsored by FAPESP, KOPPERT, and USP, coordinated by the author. Currently, 60-70 researchers are working on BC on this project (SPARCBio).

Expectations for biological control in Brazil are high. Insecticides will be part of the scene for many years, but biological control methods have begun predominating over chemical control for several crops. Thus, a "culture of biological product" has been established, similar to the occurrence of chemicals after 1940.

To firmly establish this culture, it is crucial to mobilize young and more experienced professionals engaged in this area and generate high-quality products for the producers. Training and the formation of human resources are increasingly essential to the success of BC. The number of reputable companies has grown, primarily by offering high-quality products to producers, since unavailability and/or offering poor-quality products would frustrate them in this crucial period for BC implantation. Public and private investments are essential to the success of this excellent pest control measure, especially in a country with enormous diversity and an enviable agricultural sector.

A control program using macroorganisms may proceed slowly, as in the case of *T. galloi* to control *Diatraea saccharalis*. Such a program involves inter- and multidisciplinary activities ranging from taxonomy, biological studies related to the choice of host for the rearing process, behavior, population dynamics of the pest (and the natural enemy), field studies related to the optimum times for releasing parasitoids and predators, number of insects to release, the interval of releases, etc. All these activities are followed by investigations of selectivity (in the case of chemical products used to target other pests), mathematical models involving the pest and the natural enemy, and, mainly, transfer to the producer. Certain steps take longer, such as scaling

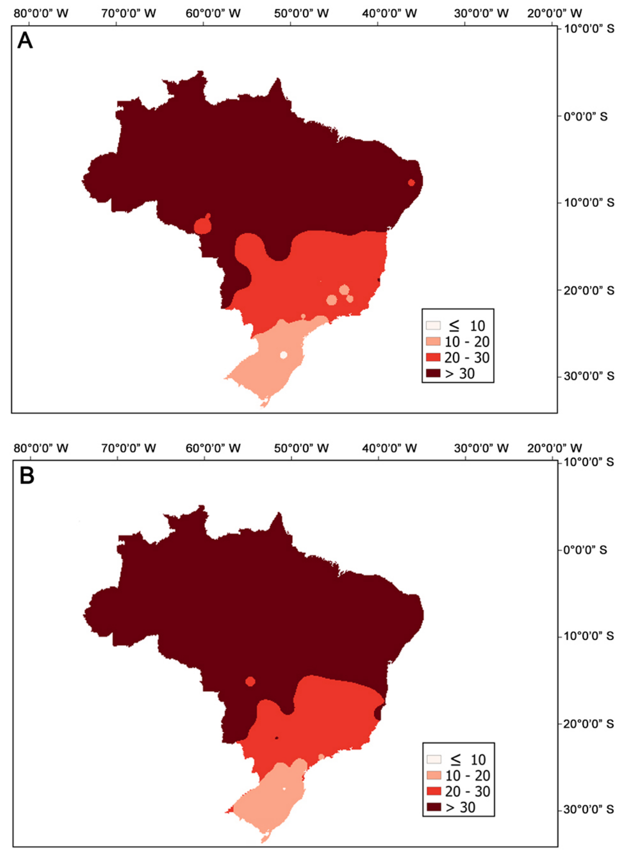

Figure 1 – Climate zones and the annual number of generations of two species of *Trichogramma* (A, T. *galloi*; B, T. *pretiosum*) in different regions in Brazil.

up the rearing process, from research in universities or institutes to field application, e.g., for an egg parasitoid, from a few grams of eggs to 40 kg produced daily in a mass-rearing facility. The cost is meager compared to chemicals, in which the synthesis costs about US$ 350 million dollars, while biological control is only US$ 2 to 5 million dollars.

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