Biological control in Brazil

Brazil's megabiodiversity and long history in the use of biocontrol mean that a wide variety of arthropod and microbial natural enemies are available for use in pest and disease management. ***Vanda Bueno*** *describes successes in different cropping systems, benefits obtained in terms of pesticide reduction and cost savings, and explores some of the factors which help or hinder wider uptake of biocontrol by Brazilian farmers.*

Before the large-scale application of chemical pesticides, biological control was one method of pest management embedded in a systems approach of pest prevention and reduction. Biological control involves the use of 'natural enemies': beneficial insects and other invertebrates which prey on or parasitise insect pests; certain types of fungi, bacteria or other microorganisms which feed on insect pests or on crop disease-causing agents; and vertebrate predators.

Augmentative biological control is the mass and regular release of beneficial arthropods or microorganisms in crops in order to boost naturally occurring levels of these natural enemies. It is commercially applied to 0.16 million km^2 worldwide. This equates to just 0.4% of the cultivated land with a cost:benefit of 1:2-5 in various cropping systems around the world[1]. Farmers are increasingly adopting augmentative biological control as a response to the growing resistance of insect and mite pests to insecticides and acaricides.

Biological control by conservation is also on the rise. This involves farm management actions that protect and stimulate the performance of naturally occurring natural enemies in and around farmers' fields.

Augmentative biological control has a number of important advantages over chemical control including: no phytotoxic effects on young plants, no early abortion occurs on fruit and flowers; the release of natural enemies takes less time and can be preferable to applying insecticides; several key pests can be controlled only by natural enemies; there is no waiting period after the release of natural enemies which allows a continued harvest with no damage to the workers' health involved in the process, and no problems with waste and to the environment[2].

Brazil is one of a few countries worldwide that has been classed as having 'megadiversity'. Brazil has a long history of biological control and between 1921 and 1944, a series of programmes introduced natural enemies to target certain pests[3]. Biological control was further boosted in the 1970s with the creation of departments of entomology and biological control at universities and research institutes[4].

Between 1990 and 2000, some 24 species of natural enemies were introduced across Brazil. These parasitoids, predatory insects and mites were used for pest control

Table 1. Commercialised arthropods controlling insect pests in Brazil

Natural Enemies	Target (pests)
Cotesia flavipes	*Diatraea saccharalis*
Trichogramma galloi	*Diatraea saccharalis*
Trichogramma atopovirilia	*Spodoptera frugiperda*
Trichogramma pretiosum	*Tuta absoluta, Pseudoplusia includens, Plutella xylostella*
Neoseiulus californicus	*Panonychus ulmi, Tetranychus urticae, Polyphagotarsonemus latus*
Phytoseiulus macropilis	*Tetranychus urticae*
Phytoseiulus longipes	*Tetranychus urticae, Tetranychus evansi*
Stratiolaelaps scimitus	*Bradysia* spp., Collembola, soil mites, thrips (pupae)
Podisus nigrispinus	Forest defoliators
Orius insidiosus	Thrips
Cryptolaemus montrouzieri	Armored scales

Trichogramma parasitoid wasps are important natural enemies

on pastures, sugarcane, wheat, tomato and on citrus orchards[5]. By 2003, augmentative biological control was being used on about 1.32 million hectares[6]. Although no current (and more accurate) data is available, there has been a considerable increase in the application of biological control over the past eight years with the bulk of the expansion taking place in the south east of the country. In this region, biological control programmes are being conducted both in small and large areas in various crops in the field and in greenhouses. Meanwhile, entomopathogenic agents, especially the fungal biopesticide *Metarhizium anisopliae* are widely used in the north east and mid west regions.

There are about 21 companies producing arthropod natural enemies, 19 companies producing fungi and viruses and 13 companies producing microbial antagonists, which can outcompete undesirable microorganisms such as common disease-causing fungi. The commercialised arthropods which feed on insect pests in Brazil are shown in Table 1.

Brazil has an area of around nine million ha cultivated with sugar cane. The most important commercial natural enemy against the sugarcane borer *Diatraea saccharalis* is the wasp *Cotesia flavipes* which parasitises borer larvae. This large biological control programme involves the annual release of the larval parasitoid to control the sugarcane borer in an area of about three million ha. The wasp parasitoid is released at a rate of 6000 parasitoids/ha. Brazil has several private companies producing *C. flavipes* and laboratories operating in sugar and alcohol production plants; the most prominent one is located in Sao Paulo State, which produces about three million of parasitoid *C. flavipes* per year. Data from the Sugarcane Technology Center (Coopersucar) located in Piracicaba-SP shows significant success in controlling sugarcane borer using *C. flavipes*: from 1980 to 2005 approximately 16.9 billion *C. flavipes* adults were released on 3.17 million ha at an average cost of US $ 4.2 per hectare avoiding the use of 951,000 litres of

Table 2. Results from biological control of sugarcane borer using the larval parasitoid *Cotesia flavipes* from 1980 to 2005

- reduction of infestation level of *D. saccharalis* from 11% to 2.6%;
- release 16.90 billion of *Cotesia flavipes* adults;
- release on 3.17 million of hectares;
- save: US$ 57 million or 951,000 liters of insecticides;
- costs of biological control: US$ 12.1 million;
- average costs per ha of biological control: US$ 4.2

Source: Sugarcane Technology Center, Brazil.

insecticides (Table 2).

A second important natural enemy that is commercialised and used as a biological control agent in several crops is the egg parasitoid *Trichogramma* spp., with a production of 15 to 20 billion *Trichogramma* per year. This parasitoid is released in an area of approximately 500,000 ha. The main species that are released as biological control agents are *T. galloi* (against sugar cane borer *D. saccharalis* eggs in approximately 400,000 ha of sugarcane), *T. pretiosum* (against *Tuta absoluta* in tomato crops and *Plutella xylostella* in crucifers plants in approximately 100 ha) and *T. atopovirilia* (controlling *Spodoptera frugiperda* in maize in > 50,000 ha) (Table 1).

Defoliator caterpillars in Eucalyptus forest areas are controlled through the small scale use (approximately 95 ha) of predatory stink bugs, primarily the species *Podisus nigrispinus* and *Brontocoris tabidus*. Forest companies with a private laboratory located in Minas Gerais state are mass rearing around 20,000 predatory bugs a month and releasing on average 2,000 predators/ha. In Minas Gerais state from 1989-2005 approximately 3,076,683 predatory adult bugs were released.

Even small organisations are developing biocontrol expertise. In Parana state a small cooperative produces the egg parasitoid *Trissolcus basalis* to control stinkbugs, such as *Nezara viridula*, which are a problem pest in soybean crops in the south of the country.

The citrus industry has employed the parasitoid *Ageniaspis citricola* to control the citrus leafminer *Phyllocnistis citrella*. From 1998 to 2004 approximately one million wasps were released in citrus orchards in the areas of the Sao Paulo state and as a result the *P. citrella* infestation decreased from 0.70% in 1999 to 0.13%.

The predatory ladybird beetle *Cryptolaemus montrouzieri* is also used on a small scale in citrus orchards against the mealybug pest *Planococcus citri*. This predator and its larvae have an average consumption of 30 mealybugs a day. The release rate is 5-25 adult ladybirds per mealybug infestation and focused in 1-5 plants in each plot (around one ha), as this predator is more effective at high prey densities.

The parasitoid *Diachasmimorpha longicaudadata*, that attacks a range of fruit flies such as *Anastrepha* spp. and *Ceratitis capitata*, was introduced in Brazil for the biological control of these pests. From 2001 to 2004 about 12 million pupae of *D. longicaudata* were released in the citrus areas of Sao Paulo State. In 2000 around 18 million *D. longicaudata* pupae were distributed all over Brazil, and a further four million were sent to French Guyana. From 2003 to 2004 about 20 million were released in the Amapa State (Amazonas region) and one million in Parana State (South region). From 1995 to 2004 a total of around 206 million *D. longicaudata* pupae were produced to control the fruit flies *Anastrepha* and *Batrocera carambolae*. This programme was conducted by governmental research institutions.

Fungal control agents are also being produced particularly in the sugar and alcohol production sector. Brazil has a major bioethanol industry. Private companies are producing the fungal biopesticide *Metarhizium anisopliae*, to act against spittlebugs like the leafhopper *Mahanarva posticata* and the froghopper *Mahanarva fimbriolata* that are found in around one million hectares of sugar cane. Other fungal biopesticides used are *Beauveria bassiana* and *Lecanicillium lecani* against pests on several crops. The commercialised biopesticides based on microorganisms in Brazil are showed in Table 3.

The use of the virus *B. anticarsiae* in Brazil against the soybean caterpillar *Anticarsia gemmatalis* increased from 1983 to 2004, reaching an area of two million ha of soybean; by 2011 however the area in use had decreased to 300,000 ha. This drop in the use of biological control is related to the increase in the area cultivated with soybean and also the lobbying of the chemical industry in Brazil. The data from the year 1999 shows that the virus was used in about 10% of the cultivated soybean area in Brazil, guaranteeing an economy superior to R$ 5 million per year. However if the use of biological control was extended to all cultivated area with soybean (11 million of ha), the value would exceed R$ 50 million per year (1 US$ = 1.77 R$).

The total area under protected cultivation (greenhouses and polytunnels) in Brazil is about 30,000 ha and most of this area is used for the production of ornamentals. The biological control of pests in greenhouses is being conducted mainly in the regions of Sao Paulo and Minas Gerais States, on ornamentals and strawberry crops.

Efforts are underway to promote the use of biological control programmes for greenhouse crops. Currently, the predatory mite *Neoseiulus californicus* is used on a small scale to control the spider mite *Tetranychus urticae* in strawberry, rose, gerbera daisy and chrysanthemum crops, as well as in peach and apple orchards. The predatory mite *Stratiolaelaps scimitus* is used to control fungus gnat larvae *Bradysia matogrossensis* in citrus seedling production and in nurseries on several ornamental plants, such as azalea, anthurium and in mushroom production. In addition, the predatory bug *Orius insidiosus* is used on a very small scale against thrips in chrysanthemum, potted gerbera, roses, and strawberries[7].

In general biological control in Brazil has been used by farmers with large plantations, but it is also used by small and medium scale family farmers. In some cases, these small and medium scale farmers have been working together in co-operatives and through these co-operatives are starting to mass rear natural enemies and distribute them to the farmers who are members of the co-operative. The mass rearing of the predatory mite *Neoseiulus californicus* against the red mite *Panomychus ulmi* is an example of this cooperation between apple farmers in Southern region in Brazil. They have built facilities for the mass rearing of the predatory mite in order to implement augmentative biological control of the apple red mite. The biological control was started in an area of 600 ha of apple orchards in 2001/2002 and increased to 7,200 ha in 2008. The biological control of the red mite showed a saving of US$ 85 per hectare when compared to the conventional

Table 3. Commercialised entomopathogenic organisms in Brazil

Fungi	**Targets**	**Crops**
Metarhizium anisopliae	spittlebugs	Sugarcane, pasture grass
Beauveria bassiana	Banana weevil, *T. urticae*, rubber-tree lace bug	Banana, papaya, rubber-tree
Sporothrix insectorum	Rubber-tree lace bug	Rubber-tree
Virus	**Targets**	**Crops**
Baculovirus anticarsiae	Soybean caterpillar	Soybean
Bacteria	**Targets**	**Crops**
Bacillus thuringiensis	Lepidoptera, Diptera	Several crops and public health uses

use of chemical control. The reduction of acaricides use for control of the red mite was around 97%.

Biological control is also increasingly being used to deal with plant diseases in Brazil. Different species of the antagonistic fungi *Trichoderma*, are being used against the disease-causing microorganisms including *Fusarium, Pythium, Rhizoctonia, Macrophomina, Sclerotinia, Sclerotium, Botrytis, and Crinipellis perniciosa* in bean, soybean, cotton, tobacco, strawberry, tomato, onion, garlic, ornamentals and cacao crops over about 500,000 hectares. The fungal biopesticide *T. asperellum* targets soilborne pathogens *Sclerotinia, Fusarium, Rhizoctonia* and *Macrophomina* in soybean, bean, and cotton crops in approximately 25,000 ha. This fungal biopesticide is used on seed and soil treatments and can be sprayed by tractor, airplane and central pivot. The cost of biological control is about US$ 30 dollars/ha with the use of *Trichoderma* while the cost of fungicides is about US$ 75 dollars/ha. The bacterial biopesticides *Bacillus subtilis* and *B. lechiniformis* are used against the nematodes *Meloidogyne incognita, M. javanica, Pratylenchus brachyurus* and *P. coffeae* in potato and carrots crops. In the year 2008 more than 12,000 kg of *Bacillus* spp. (2x1010) was commercialized for nematode control in potato and carrot crops, and was applied by irrigation and seed treatment (5 to 10 kg/ha) a cost of US$ 160-300/ha.

The future of biological control in Brazil

In 1998, Brazil imported US$ 1.2 billion in pesticides, and from 1984 to 1998 there was an increase of 700% in the use of active ingredients. In 2009, Brazil ranked as number one in the world for use of pesticides, using 673.9 million tons of the formulated product at a value of US$ 7.125 billion. The crops with the highest pesticide use in descending order are: tomato, potato, citrus, cotton and coffee crops. Tomatoes, receive on average 52.5 kg of active ingredient/ha.

Several pests are present both in greenhouses and in fields and they are still largely controlled by chemicals. However, this situation is changing and there are several stimuli for the adoption of biological control strategies as an IPM component, not only for export markets, but also as a mainstream sustainable plant protection method in greenhouses. According to Celli, the use of IPM can provide new commercial opportunities for growers as a result of 'green labels' that provide certification for environmentally-safe production techniques and lack of pesticide residues on fruit. In order to minimise the effect of pesticides on fruit and ornamental production and to ensure production sustainability, two guidelines were published for the Brazilian Ministry of Agriculture, Livestock and Food Supply (Ministério da Agricultura, Pecuaria e Abastecimento – MARA) with provisions on General Guidelines and Technical Regulations for Integrated Fruit (FIP) and Ornamentals production, in order to allow the production of quality fruit crops with the minimum of environmental contamination.

As outlined above, biological control of pests and disease is widespread in Brazil, although application is still limited considering the area under crop production. In many cases, produce are destined for the local market and are not subject to any controls regarding pesticide residues; the situation of the export market however is quite different.

There are several stimuli that are pushing growers to use fewer pesticides and adopt more sustainable methods to protect plants, and biological control is becoming a reality with great promise for all involved in agriculture and food production.

Research in Brazil has concentrated on the use of native natural enemies, or on natural enemies that were introduced to Brazil a long time ago. This stems from concerns over the environmental risks of imported natural enemies and also because native or naturalised natural enemies are well adapted to the environmental conditions of Brazil. The use of augmentative biological control is increasing in regions throughout Brazil, and it is likely that use will continue to grow in the future, both in Brazil and across the world.

There are several incentives for the use and implementation of new biological control programmes:

- Brazil has enormous biodiversity, and many natural enemies (beneficial insects and mites) occur and have proven to be good natural enemies for biological control, or are available to be evaluated and used as biological control agents. This may mean it is possible to control the majority of pests with native natural enemies
- high interest by the farmers, because of the development of resistance of pests to pesticides and demands from the export market for reduced pesticide use.

However, additional measures are needed to increase the use of biological control in Brazil: critical analyses of possibilities for biological control (addressing the lack of commercial availability of natural enemies, and lack of biological control technology transfer), a more critical government approach and a more professional approach by industry. There are enormous possibilities for biological control, but they are seriously frustrated by lobbying from the chemical pesticides industry and a total lack of governmental support. With Brazil's high ranking for pesticide use across the world, it is necessary that steps are taken to change this.

The pesticide industry considers biological control as cumbersome and of restricted use, most farmers have become reliant on pesticides during the past 60 years, governmental institutions do not enforce or stimulate non-chemical pest control and many regulations concerning the collection and application of biological control agents delay or even prohibit their use. Recent developments however may lead to a promising future for augmentative biological control. In addition to the ever-growing number of pests that are becoming resistant to pesticides (resulting in a need for alternative control methods), the requirements of residue free food by supermarkets and the prioritisation of the use of IPM by governmental institutions like the European Union, along with the termination of pesticides subsidies, will all improve the conditions for biological control. After 60 years of chemical control, we are entering the ecology-based pest management era[8].

The most realistic possibilities for growth of a biological control market in Brazil are in controlling pests on sugarcane crops, as still there are 6 million ha available for biological control and it involves a very simple system for mass rearing and commercialisation. The other major opportunity is in soybean crops, as there are millions of hectares and it also involves a simple system and programme that has been used. Maize, cotton, orchard and greenhouse crops are more complicated systems but are still great possibilities for the use of biological control.

Despite its problems, augmentative biological control plays an effective role in programmes of IPM worldwide and there is no doubt that Brazil will play a great role in increasing the area of cropland under biological control, both in greenhouse and field conditions.

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