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Trichogramma in Brazil: Feasibility of Use after Twenty Years of Research

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RESUMO - São apresentados os resultados dos estudos com *Trichogramma* no Brasil, especialmente aqueles desenvolvidos na ESALQ/USP, nas últimas duas décadas (1984-2004). O projeto, envolvendo desde a taxonomia, técnicas de criação, aspectos biológicos e comportamentais das pragas e dos parasitóides, dinâmica populacional das pragas, técnicas de liberação,estudos de seletividade, avaliação da eficiência, pode ser considerado um modelo e foi seguido por outros programas de controle biológico no Brasil e na América Latina. O programa gerou inúmeras publicações, permitindo a formação de recursos humanos na área, abrindo novas áreas de pesquisa e mostrando que o parasitóide pode ser usado no controle de pragas-chave do algodoeiro, cana-de-açúcar, grãos armazenados, hortaliças, milho, soja e tomateiro. As perspectivas do uso do parasitóides possibilitaram a criação de empresas para comercializá-los no Brasil, transferindo mais facilmente a tecnologia ao usuário.

PALAVRAS-CHAVE: Trichogrammatidae, parasitóide de ovos, controle biológico aplicado

ABSTRACT - Results of studies with *Trichogramma* in Brazil are presented, especially those developed at ESALQ/USP in the past two decades (1984-2004). The project involved taxonomy, rearing techniques, biological and behavioral aspects of the pests and parasitoids, pest population dynamics, release techniques, selectivity studies, and efficiency evaluation. It can be considered a model project and has been adopted by other biological control programs in Brazil and Latin America. The program has given rise to a number of publications, allowing the formation of human resources in this area and opening new research areas. The results indicated that the parasitoid can be used to control key pests in cotton, sugarcane, stored grain, vegetables, corn, soybean, and tomato. The perspective of using the parasitoid has stimulated the creation of companies to commercialize it in Brazil, thus more easily transferring this technology to users.

KEY WORDS: Trichogrammatidae, egg parasitoid, applied biological control

Trichogramma species (Fig. 1) are among the most reared and used natural enemies in the world. Every year, they are released in more than 16 million ha, in annual (for the most part) and perennial crops (Hassan 1997, van Lenteren 2000), even though Smith (1996) had reported their use in 32 million ha. Worldwide, 28 *Trichogramma* species are released in 28 crops (Hassan 1988). These are among the most frequently studied insects, with several books published about their efficiency in biological control (Wajnberg & Hassan 1994, Parra & Zucchi 1997).

Studies on *Trichogramma* began in the last century, when Flanders (1927) discovered the possibility of rearing it on a factitious host, *Sitotroga cerealella* (Oliv.). Since then, there has been great interest in the parasitoid, because of its efficiency and ease of multiplication. In Brazil, studies began in the 1940's to control *Neoleucinodes elegantalis* (Guenée) in tomato (Gomes 1963). Papers by Moraes *et al.* (1963) came next, targeted at forest lepidopterans.

In the 20th century, since the researches by Flanders (1927), several countries, especially the USA, started to use it. However, these initial programs were in general inadequately-planned and isolated projects without inter- and multidisciplinary characteristics. Thus, many errors were committed and the expected efficiency was not achieved because of a lack of knowledge or misevaluation of the following items: (1) egg density of the target pest; (2) *Trichogramma* species unsuitable for controlling the target pest; (3) quality control of the parasitoid produced; (4) number of parasitoids released, and form of release; (5) pest dynamics and phenology of the plant; (6) competition with other biological control agents; (7) effect of chemical products (selectivity) on *Trichogramma* in crops where several pests occurred (Parra *et al.* 2002). These errors led this egg parasitoid to be discredited with regard to its efficiency. However, some important findings in the 1970's, such as the use of male genitalia for species identification (Nagarkati & Nagaraja

Figure 1. *Trichogramma* on eggs of agricultural pests. A) *D. saccharalis*; B) *H. virescens*; C) *S. frugiperda*; D) *T. absoluta*.

1971) and the use of *Anagasta kuehniella* (Zeller), which was nutritionally more suitable than the moth *S. cerealella* used until then (Lewis *et al*. 1976), allowed a reflexion on the use of this parasitoid. With support from IOBC and from *Trichogramma* work groups, studies were resumed worldwide, under a more modern and adequate view concerning the reality of those times.

Biological control programs for agricultural pests in Brazil began with Jean Voegelé (INRA, Antibes), one of the leaders in studies involving *Trichogramma* in the 1980's, who taught courses in Brazil, encouraging Brazilian researchers to develop researches with *Trichogramma.* The interest in developing studies with this egg parasitoid was sparked at ESALQ (Entomology) and, in 1982, the senior author of this work (JRPP) visited the INRA and, in 1984, together with a group of researchers and with the support from a taxonomist (RAZ), the program was started, based on the French model, primarily targeted at the control of *Diatraea saccharalis* (Fabr.) in sugarcane and *Heliothis virescens* (Fabr.) and *Alabama argillacea* (Hueb.) in cotton. This program involved the following stages: collection, identification and maintenance of *Trichogramma* spp. strains; selection of a factitious host for the mass rearing of the parasitoid; biological and behavioral aspects of *Trichogramma* spp.; egg dynamics of the target pest; parasitoid release, number of released parasitoids and release points; season and form of release; selectivity of agrochemicals; efficiency evaluation; pest/parasitoid simulation model.

The objective of this paper is to show the advances that occurred 20 years after the program was started, the example followed by other biological control programs, publications produced, human resources formed, new research areas that were initiated in the country, as well as the feasibility to use the parasitoid on different crops in Brazil.

Studies on *Trichogramma*

Collection, Identification and Maintenance of *Trichogramma* Strains. Until the 1970's, since *Trichogramma* was considered nonspecific, individuals of a given species, collected in areas with different climatic characteristics, were used to control pests in geographically distinct regions. Currently, microclimatic specificities are admitted within the same species. For this reason, it is essential to maintain properly labeled, separate strains in the laboratory, in order to ensure the genetic heritage of the initial population.

The presence of a taxonomist is indispensable for this type of program, since an erroneous identification or the lack of it could result in failure of the program. A collection of strains exists at ESALQ, collected from different points of the country. This collection must be supervised by a taxonomist to avoid errors common in the past.

T. minutum Riley was, for a long time, referred as the species parasitizing *D. saccharalis* in Brazil. Today, it is known that this species does not occur in Brazil (Parra & Zucchi 1986). Due to the minute size of *Trichogramma* species (0.20

mm), precautions must be taken, such as maintaining the rearing at separate locations; if this measure is neglected, interspecific competition may occur, with predominance of the most aggressive species (Parra *et al*. 2002).

There are about 200 species of *Trichogramma* described worldwide (Pinto 1999). In Brazil, 28 species have been recorded, of which one half were described during the studies conducted at ESALQ (Zucchi 1988; Querino & Zucchi 2003 a,b), the characterization of several species based on morphology (Querino & Zucchi 2002 a,b) and on molecular techniques (Ciociola *et al*. 2001 a,b,c). The most recent list of *Trichogramma* species in Brazil and their corresponding hosts was prepared by Zucchi & Monteiro (1997). Information about the species contained in the collection at ESALQ is available on the *web* (Querino & Zucchi 2001).

Selection of Factitious Hosts for Mass Rearing of Parasitoids. Even though several factitious hosts exist for rearing *Trichogramma*, many researchers still prefer to use *S. cerealella*, because it is easy to rear, despite being less adequate for the multiplication of the parasitoid in relation to other species, such as *A. kuehniella* and *Corcyra cephalonica* (Stainton) (Lewis *et al*. 1976; Parra *et al*. 1991, 1997; Gomes 1997; Gomes & Parra 1998; Bernardi *et al*. 2000). In order to compensate for this lower nutritional quality, *T. pretiosum* Riley reared on *S. cerealella* should be released in greater numbers (in relation to those reared on *C. cephalonica* and *A. kuehniella*) to control *H. virescens* in cotton.

Therefore, it is essential to associate the nutritional quality of the host, to produce parasitoids that are competitive with those in nature, with a rearing technique that enables mass production of *Trichogramma*. Since the Chinese have extensive silkworm rearing at their disposal, they also use *Philosamia ricini* (Drury) and *Antheraea pernyi* (Guérin-Méneville) eggs or ovules in *Trichogramma* rearing.

In general, *A. kuehniella* has proved to be the most suitable factitious host for the Brazilian species (Parra *et al*. 1991, Gomes & Parra 1998), although, according to Gomes (1997), *C. cephalonica* is the best rearing host for *T. galloi* Zucchi, a predominant parasitoid of *D. saccharalis* eggs in most of Brazil.

The influence of biotic (mating, oviposition, adult feeding) and abiotic factors (temperature, relative humidity, and photoperiod) was exhaustively studied in a number of papers and book chapters published on the subject (Parra 2002).

Biological and Behavioral Aspects of *Trichogramma* spp. Basic studies were conducted for the main *Trichogramma* species collected in Brazil, such as strain selection, temperature requirements for laboratory production and for insect adaptation in the field, humidity requirements, determination of the most suitable parasitoid:host eggs ratio, adaptation to the factitious host (number of generations to achieve it), parasitism capacity, and behavior. In recent years, the findings that *Trichogramma* has only a single instar (Volkoff *et al.* 1995, Dahlan & Gordh, 1996) and the influence of symbionts, especially *Wolbachia*, on the sex ratio of *Trichogramma* (Stouthamer *et. al.* 1990), have been taken into account without, however, forsaking the classic papers by Lund (1934), Doutt (1959), Buttler & Lopes (1980), and Calvin *et al.* (1984), among others.

Quality control must be a constant procedure in laboratory populations, as well as the periodic introduction of wild populations and even rearing the parasitoid on the natural host after a number of generations have been reared on the factitious host. *T. pretiosum* populations can withstand high inbreeding rates in laboratory rearing, without showing evidence in their biological characteristics of degenerative reflexes that would compromise their quality (Prezotti *et al*. 2004).

Egg Dynamics of Target Pests. This has been one of the least-studied items in our country, albeit essential for defining the season when the parasitoid should be released, i.e., at the onset of the population of adults and, consequently, of eggs. There have been attempts to use the plant's phenology as groundwork for parasitoid release (Lopes 1988); all other studies are based on the pest's dynamics with the use of pheromone – *E. aurantiana* (Lima) – or through the on-site evaluation of the plant structure that harbors eggs (most crops).

Parasitoid Release: Numbers, Places, Seasons and Ways. Once the release season has been defined, the parasitoid's dispersal ability must be evaluated (Lopes 1988, Sá *et al*. 1993, Zachrisson & Parra 1998) to determine the number of release points. The form of release can be very simple, such as releasing the emerged adults from plastic or glass containers by walking through the field, or in a more sophisticated manner, by airplane, using starch capsules (biodegradable) which allow the parasitoids to exit but prevent predation (patented by the INRA, France). In Brazil, "Bug Agentes Biológicos" (an insect-selling company) has developed a similar capsule, which has been largely used. One of the great problems in tropical countries is the predation of pupae after release. Thus, the action of predators must be taken into account when *Trichogramma* is released in the form of pupae (Pinto 1999). Releases using a center pivot were used in Brazil for *T. pretiosum* in tomato (Haji *et al*. 2002).

The number of parasitoids to be released must be defined in laboratory, semi field, and field tests. In sugarcane, Lopes (1988) estimated the proportion of 1.6 parasitoid (*Trichogramma* spp.) per egg of the pest as ideal. Sá (1991) found a ratio of 10.7 *T. pretiosum* per egg of *Helicoverpa zea* (Boddie) in corn, while Zachrisson (1997) found a 5.3 ratio of *T. pretiosum* per *Anticarsia gemmatalis* (Hueb.) egg in soybean. In perennial crops, this number can be quite higher (36 parasitoids per egg for the citrus fruit borer, *E. aurantiana*) (Molina 2003). In general, the literature has recorded, in citrus and other fruit crops, releases varying from 70,000 to 3.8 million parasitoids/ha, or 9,000 to 50,000 parasitoids/plant (Oatman & Platner 1985, Hassan *et al*. 1988, Newton & Odendaal 1990, Glen & Hoffmann 1997, Mills et *al*. 2000). In many countries, fixed numbers of parasitoids are released for the sake of ease, regardless of the existing population of the pest. This could be one of the reasons for the lack of success of the parasitoid.

Egg parasitism by *Trichogramma* on different days in the same release card can extend the period of action of the parasitoid (Pinto 1999).

Selectivity of Agrochemicals. In crops that have a large number of pests and require the application of agrochemicals, selectivity studies must be done to establish an interval between parasitoid release and the application of such products. These selectivity tests must be based on IOBC rules to allow comparisons with other countries (Hassan 1997). Only a few papers on selectivity have been done in Brazil (Foerster 2002, Degrande *et al*. 2002).

Efficiency Evaluation. Efficiency and cost must be compatible with the crop and comparable to traditional control methods. Thus, a crop such as tomato, with high profitability, allows up to 10 *Trichogramma* releases per crop cycle. Other crops with a lower profitability, like sugarcane, do not allow more than 3-4 releases in most years.

Pest/Parasitoid Simulation Model. Parasitoid-pest simulation models are developed on specialized software programs, based on biological data about the pest and its natural enemies. These models for *Trichogramma* can be developed in Brazil, because the number of basic researches involving this parasitoid along these 20 years has been expressive. However, lack of simulation specialists prevents us from having these models at our disposal.

The need of a group of specialists in order to develop an applied biological control program is evident. Thus, a taxonomist, a biologist, an ecologist, a specialist on agrochemicals, an entomologist-economist, and a computer science specialist must work together. Evidently, in this case, the chances of obtaining success are much higher than if the program is developed only by an entomologist with a general formation.

Studies with *Trichogramma* in Brazil

The research on *Trichogramma* has spread throughout Brazil, resulting in the appearance of other study groups involved with this subject. However, except by some cases, like the use of *T. pretiosum* to control *Tuta absoluta* (Meirick), the releases on cotton by Embrapa Algodão, in Paraíba State, the sporadic use of *T. atopovirilia* Oatman & Platner and *T. pretiosum* to control *Spodoptera frugiperda* (J.E. Smith) in corn and *Plutella xylostella* L. in cabbage, the project has not reached large areas, due to the difficulty in transferring the technology, and particularly to the lack of good quality insects available for the farmer.

The volume of information and results are very interesting and liable to be used in crops such as cotton, soybean, sugarcane, tomato and other vegetables, corn, stored grain pests, etc. In addition, Garcia (1998) and Molina (2003) demonstrated the potential of use of *T. pretiosum* in citrus to control *E. aurantiana* (Lima), the citrus fruit borer; in avocado, the parasitoid is being studied to control *Stenoma catenifer* Wals. (Hohmann & Meneguim 1993); in agricultural crops, *T. pretiosum, T. atopovirilia*, and *T. galloi* have shown the greatest potential of use in our country.

Corn. In both sweet and commercial corn cultivars, results are better on *H. zea* control, since the egg-laying scales of *S. frugiperda*, disposed in layers, make parasitism difficult (Sá 1991, Beserra 2000). *Trichogramma* releases have been recommended in areas attacked by *S. frugiperda* (Cruz *et al*. 1999), with good results.

Several basic studies have been performed to control *H. zea* with *T. pretiosum* (Sá & Parra 1994a), with natural parasitism by *T. pretiosum* reaching 95% (Sá & Parra 1994b). When releases are recommended at the rate of 11 parasitoids per *H. zea* egg, and taking into account the parasitoid's dispersal, such releases should be done at a great number of points per hectare (Sá *et al*. 1993). Three releases of 100 thousand *T. pretiosum* adults/ha reduce 26% of *H. zea* damage on corn (Sá 1991). Rivero (1992) also conducted basic researches with *H. zea* versus *T. pretiosum*, indicating that the parasitoid could yield from 4.8 to 8.5 times more generations than the corn earworm. Beserra (2000) observed that egg parasitism in *S. frugiperda* is low and concentrated at the bottom and medium parts of the plant. Although occurring in smaller numbers in the field, *T. atopovirilia* shows higher parasitism capacity than *T. pretiosum*. According to this author, the presence of scales on *S. frugiperda* egg masses is the main factor that contributes to decrease *T. atopovirilia* and *T. pretiosum* potential of parasitism. Also, the distribution of eggs in layers prevents egg parasitism in the lower parts by *T. atopovirilia* (Table 1).

Table 1. Parasitism capacity of *T. atopovirilia* in a shade-netting structure on *S. frugiperda* egg masses with different physical characteristics (Beserra 2000).

Mass	Parasitism (%)
One layer	66.2
Two layers	45.2
Three layers	40.1

Cotton. Entomologists at Embrapa Algodão, in Campina Grande, PB, have conducted excellent works with *T. pretiosum* to control the cotton leafworm, *A. argillacea*. The potential to use *T. pretiosum* has also been demonstrated for *H. virescens* (J.R.P. Parra, unpublished). At Embrapa, a system adapted from the Colombian model for rearing the parasitoid on *S. cerealella* eggs has been adopted (Almeida 1996).

The pioneering works in Brazil were conducted by Bleicher (1985) involving three *T. pretiosum* populations aimed at controlling *A. argillacea*, with parasitoids reared on *A. kuehniella*.

Life table results confirmed the biological data, and the *T. pretiosum* population from Iguatu, CE, was the most aggressive (Bleicher & Parra 1990a, 1991). Temperature requirement studies were also carried out, showing that the biology of *T. pretiosum* is influenced by the collection locality (origin). Between 2.7 and 2.9 *Trichogramma* generations were observed for each generation of *A. argillacea* (Bleicher & Parra 1989, 1990b). The parasitoids' longevity was higher when they were given a chance to parasitize and when they were fed pure honey.

Sugarcane. The bulk of the information about *Trichogramma* is concentrated on this crop. Some of the studies deal with: identification of predominant species in Brazil – especially *T.*

galloi Zucchi and *T. distinctum* Zucchi – by conventional (Zucchi *et al*. 1991, Zucchi & Monteiro 1997) and molecular methods (Ciociola Jr. *et al*. 2001a,b); temperature (Parra *et al*. 1991) and humidity requirements (Parra & Sales 1994); most suitable factitious host (Gomes & Parra 1998); different developmental stages of the parasitoid's biological cycle (Cônsoli *et al*. 1999); spatial and temporal distribution of *D. saccharalis* eggs and their parasitism by *T. galloi* (Micheletti 1987); effect of natural and fastitious host egg age on the development and parasitism of *T. galloi* and *T. distinctum* (Lopes & Parra 1991); effect of constant and fluctuating temperatures on the development and parasitism of *T. galloi* (Cônsoli & Parra 1995a,b); photoperiod effect on the biology of *T. galloi* (Cônsoli & Parra 1994); artificial infestation methodology of *D. saccharalis* eggs for studies with *Trichogramma* (Lopes *et al*. 1989); determination of the parasitoid's range of action (10 m) and number of *T. galloi* to be released per *D. saccharalis* egg (1.6:1) (Lopes 1988); and efficiency of *T. galloi* individually or in association with *C. flavipes* in field evaluations (Botelho *et al*. 1999). These were followed by parasitism studies of *T. galloi* in sugarcane varieties, conducted at different row spacing (Botelho *et al*. 1995a,b). Studies on the selectivity of chemical products to *T. galloi* were also conducted (Cônsoli *et al*. 2001), as well as studies on release techniques (Pinto 1999).

Field results were outstanding; the association of one release of *Cotesia flavipes* (Cameron) with three releases of *T. galloi* was the most efficient, resulting in a reduction of the infestation intensity of 60.2% relative to the control (Table 2). This treatment (three releases of 200 thousand *T. galloi* per week and one release of 6 thousand *C. flavipes*) was much superior to the control, i.e., better than *C. flavipes* individually, because in this case, the reduction in relation to the area where releases were made was only 16.1%. These results attest the feasibility of using *T. galloi*, especially in areas where egg predation is low and *C. flavipes* is not well adapted.

Soybean. In some regions in Brazil, egg parasitism of *A. gemmatalis* by *T. pretiosum* is sometimes higher than 90% (Zachrisson 1997). This author showed that the proportion of 5.3 parasitoids per *A. gemmatalis* egg allows a high parasitism rate, regardless of the phenological stage of soybean.

Aspects related to temperature requirements, plant phenology, parasitism, and strain effect on parasitism, among others, were also studied. The dispersal ability of *T. pretiosum* to parasitize *A. gemmatalis* eggs in 24h is 8 m and corresponds to a dispersal area of 77 m^2 (Fig. 2). Thus, the release of *T. pretiosum* to control *A. gemmatalis* should be performed in 130 points per ha, with a control efficiency of 64.8% (Zachrisson & Parra 1998). Its potential to control *A. gemmatalis* is rather great, since five *Trichogramma* species have already been collected parasitizing this pest (Foerster & Avanci 1999, Avanci 2004).

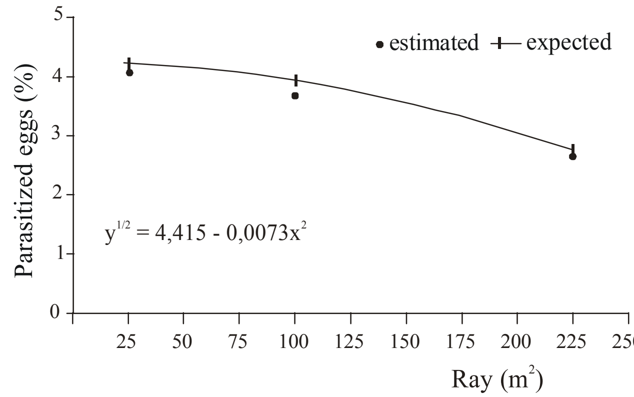

Figure 2. Mathematical relation between the dispersal range of *T. pretiosum* and the number of *A. gemmatalis* eggs parasitized (Zachrisson & Parra 1998).

Stored Grain. Studies conducted by Inoue (1997) demonstrated the potential of *T. pretiosum* to control *S. cerealella* in stored corn, both in bulk and on the ear. The storehouses, being stable ecosystems, experience high temperatures, what favors parasitism, as reported by Inoue & Parra (1998), who found 97.6% of the females parasitizing at 30ºC.

The parasitoids released in the grain mass are capable of parasitizing *S. cerealella* eggs at depths of up to 40 cm, and the percentage of parasitism decreases, on average, 1.9% for each cm of depth in the corn grain mass. For greater control efficiency, the release should be made in the beginning of the attack by the moth, at a rate of 12 parasitoids per *S. cerealella* egg. For ear corn, releasing *T. pretiosum* is efficient to control *S. cerealella*, reducing the population of adult moths by 60.7% and the damage caused to stored ears in screened warehouses by 63.1%. The association of *T. pretiosum* with *Bracon hebetor* Say did not result in advantages in the control of *S. cerealella* in comparison with the release of *T. pretiosum* alone; however, numerically there is a tendency for greater efficiency when both species of parasitoids work in association (Inoue 1997) (Table 3).

Tomato. Studies with the moths – *T. absoluta* and *Phthorimaea operculella* (Zeller) – and the borer – *H. zea* and *N. elegantalis* – in tomato have shown the feasibility to use *T. pretiosum* in

Table 2. Percentage of reduction in infestation intensity (II %) by *D. saccharalis* after using different biological control tactics in sugarcane. Brasilândia, MS (Botelho *et al*. 1999).

Treatments	Number released/ha	II % Reduction
T. galloi (one release) + *C. flavipes* (one release)	200,000 + 6,000	27.0
T. galloi (two releases) + *C. flavipes* (one release)	200,000 + 6,000	33.4
T. galloi (three releases) + *C. flavipes* (one release)	200,000 + 6,000	60.2
C. flavipes (one release) – control 1	6,000	16.1
No release – control 2	-	0.0

Table 3. Damage percentage in stored corn grain due to the attack of *S. cerealella* after parasitoid release (Inoue 1997).

Treatments	Parasitoid : pest ratio released	Pest population reduction (%)	Damage reduction (%)	Damaged grain (%)
T. pretiosum	1:5	60.7	63.1	7.7
T. pretiosum + *B. hebetor*	1:5 + 1:112	69.4	70.1	6.0
No release - control	-	-	-	18.9

this vegetable crop. Excellent results have been obtained in the greenhouse, in sprawling, and in staked tomatoes.

In the greenhouse, results are very good for *T. absoluta*, but it is necessary to select strains to control *N. elegantalis*, the tomato fruit borer; weekly releases are recommended, at the rate of 6.4 parasitoids per *T. absoluta* egg, based on leaflet samplings. A control of 87% with *T. pretiosum* releases in relation to the 42% of control was obtained with the growth regulator lufenuron (J.R.P. Parra, unpublished).

In practical terms, the excellent results obtained at Vale do São Francisco, Pernambuco State, in the control of *T. absoluta* atest the feasibility to use this parasitoid. There are many other basic studies with *T. pretiosum* for the control of *P. operculella* and *T. absoluta*, based on biological studies (Pratissoli & Parra 2000a), fertility life table (Pratissoli & Parra 2000b), and on parasitism capacity (Pratissoli 1995). It has also been demonstrated that cluster analysis is a suitable method for selecting *Trichogramma* strains (Pratissoli & Parra 2001).

Several selectivity studies on products used in the crop have been conducted (Cônsoli *et al.* 1998, Carvalho *et al.* 1999). Papa (1998) recorded excellent results in staked tomato by releasing 800 thousand parasitoids (*T. pretiosum*) per ha, with a control efficiency similar to the use of insecticides.

For *H. zea* in processing tomato, Moreira (1999) achieved a control efficiency of 83% in the field, releasing 400 thousand *T. pretiosum* parasitoids per ha, at weekly intervals, with variable results depending on the strain's origin.

Final Considerations

Twenty years after a steady flow of *Trichogramma* studies in Brazil began, there are still some problems to be solved. One of them is the availability of insects for the farmer, which is beginning to be resolved presently as insect-selling companies arise, similarly to what is happening in other countries in the world. Even field assays, which for many were considered insufficient, will be improved with such availability of insects. One of the great worldwide hindrances to the development of biological control programs is the technology transfer provided to the user; this worldwide problem could be solved by the above-mentioned companies themselves. It becomes clear that, in these cases, production scale changes would have to be implemented as compared to laboratory research needs. For this reason, it is essential that constant quality control should be maintained by insect suppliers, always under the supervision and follow-up of Research Institutions and Universities.

However, the high volume of information on *Trichogramma* species, obtained from books, bulletins, congress abstracts, dissertations, theses, and national and international periodicals, has allowed great advances in the area of biological control and, especially, because this study model has served as a basis for researches with other parasitoids and predators in Brazil. *Trichogramma* study groups were formed in several states, such as Espírito Santo, Rio Grande do Sul, Paraná, Rio de Janeiro, Mato Grosso, Santa Catarina, Paraíba, Pernambuco, Minas Gerais, and groups also found motivation elsewhere in Latin America countries, such as in Chile, Uruguay, Argentina, Paraguay, and Panama.

Concurrently (and in this maybe consists the high proceeds of all basic research that has been developed), cutting-edge studies were conducted in the area of "in vitro" production of *Trichogramma* (Parra & Cônsoli 1992, Cônsoli & Parra 1999, Cônsoli & Parra 2002) and other parasitoids (Magro & Parra 2004), placing Brazil in the vanguard of this type of study, as a leader in Latin America, and putting the country at a level playing field with developed countries. These studies will enable advances in the area of hosts/natural enemies' relations, allowing greater development in a short period of time, including rearing techniques for parasitoids and predators.

Although still timidly, more intense use of *T. pretiosum* is being made to control *T. absoluta* in tomato, both in field areas and under protected cropping, *P. xylostella* in cabbage, based on results by Barros (1998), and in corn areas with *T. atopovirilia* and *T. pretiosum* to control *S. frugiperda*, though in this case with the previously indicated limitations. In Brazil, between 5 and 10 billion *Trichogramma* wasps are produced annually, and released in 60,000 ha of corn and in 1,000 to 1,200 ha of tomato and crucifers (cabbage), with a perspective for significant increase in a very near future.

The potential of use in sugarcane, cotton, vegetables, fruit trees, and soybean, among others, as well as the other advantages indicated, give a dimension of the work that has been performed and the progress that has been accomplished along 20 years of studies with *Trichogramma* spp. in Brazil.

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