# ACCOMPLISHMENTS AND FUTURE OF BIOLOGICAL CONTROL AND INTEGRATED CONTROL IN BRAZIL – PART 3

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## EDITOR'S NOTE

The entomologist Kenneth Sverre Hagen, professor of the University of California at Berkeley, and that moment working in the Michigan State University, was in Brazil for a three month period in 1977 as a consultant in the Program of Superior Agricultural Education (*Programa de Educação Agrícola Superior – PEAS*) of the Ministry of Brazilian of Education and Culture. During this period (from July to September), Professor Hagen trained and changed experiences with docents (university professors) and researchers in several fields mainly in the Biological Control of Insects and Pests using ESALQ (Superior College of Agriculture) as a basing point. He visited other Brazilian Universities and Research Institutions. All of the activities are presented in the Report Biological and Integrated Control of Insects in Brazil (*Controle Biológico e Controle Integrado de Insetos no Brasil: Realizações e Futuro*), a never published document. During his stay in Brazil, he was accompanied by a professor from the Entomology departament, responsible for rescuing this report. Of an invaluable historical nature, the report will be published in three parts in the Brazilian Journal of Agriculture (BJA), opening the "*Unpublished historical papers*" section.

## LEPIDOPTERA

There have been at least 33 different species of Lepidoptera partially to completely controlled in various countries of the world (Huffaker and Messenger 1976). In Brazil, apparently only one main species, *Diatraea saccharalis*, has had imported parasites released against it, and these efforts over the years accompanied with periodic releases of parasites and under an integrated control approach has resulted in from partial to substantial control of the sugar cane borer in Brazil. (See also *G. molesta*).

There are at least 14 accidentally introduced lepidopterous pests in Brazil. A search in the Amazon basin for at least egg parasites of *Castnia lious* (Drury) may be warranted. There are many parasites of *Bucculatrix thurberiella* Busk present in Arizona and California should the pest become serious enough in Brazil to call for a biological control program. Perhaps another moth pest *Plutella maculipennis* that if economically important enough, parasites could be imported.

The sphingid pest of casava in Brazil today may be so serious as to call for mass culturing and periodically releasing a common trichomatid egg parasite that is naturally present in Minas Gerais. Mass culture techniques of producing *Trichogramma* have already been developed in Brazil. Currently the Federal University of Minas Gerais cooperating with the Companhia Industrial Agrícola at Belo Horizonte are mass culturing *Trichogramma machacalini* for release against the butterfly *Eucelasia Riodinidae* should this pest begin to increase in eucalyptus farms.

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## LIST OF PEST LEPIDOPTERA SUSPECTED TO BE INTRODUCED INTO BRAZIL

### Castniidae

- *Castnia licus* (Drury) - Bananas, sugar cane, orchid

A Neotropical species. It also occurs in India. In Brazil no insect parasites have been found thus far associated with it, but Guagliumi (1973) reports an entomogenous fungus attacking it. Its origin if it did not come with the importation of bananas into Central or South America could be the Amazon basin; therefore parasitic insects may be present there and did not follow the pest into the coastal belt of Brazil where sugarcane is grown.

### Crambidae

- *Diatraea saccharalis* (F.) - Sugar cane, rice, grasses

Neotropical. Possibly originated in the Amazon basin. This pest has received the greatest attention of entomologists in Brazil. A successful integrated control program has evolved over many years of research. Gomes (1962) presented the pioneering biological control efforts, and Guagliumi (1973) describes in detail the history and control of all sugarcane pests including *D. saccharalis*. He lists three egg parasites, twenty four larval or pupal parasites, two fungi and nine predaceous insects attacking the sugar cane borer. The most recent history of the evolution of the biological control of the sugar cane borer in Brazil is Gallo *et al.* (1977). These authors trace the history from 1932 when the Amazon fly *Metagonistylum minense* Town. was discovered in the State of Minas Gerais parasitizing the sugar cane borer and later this tachinid was found in the Amazon attacking the borer on gramineous plants. Gallo (1949) studied the biology and mass cultured the Amazon fly for release in the field. In the meantime, Souza (1942) discovered another important tachinid *Paratheresia claripalpus* Wulf that attacked the borer. Gallo (1951) successfully introduced the tachinid *Lixophaga diatraeae* Town. from Cuba into Brazil. To aid the control of the borer in São Paulo state, the Department of Entomology of ESALQ/USP increased lab production of the tachinids and these were released by the large sugar companies in their plantations. In recent years the same workers at ESALQ developed the use of artificial diets to culture factitious lepidpterous hosts for rearing the parasites, and today the large sugar companies have adopted the technology and produce their own parasites for release in the field.

Earlier *Trichogramma minutum* from a native pyralid was mass cultured on various moth eggs and realeased.

Another breakthrough in the biological control of the sugar cane borer was the introduction of *Apanteles flavipes* cam. from India, where it attacked an entirely different lepidopteran, to the Island of Barbados. Here along with *L. diatraeae* completely controlled *D. saccharalis* (Alam *et al.* 1971). *A. flavipes* was later introduced into Brazil, 1974, and became successfully established. Planalsucar labs in N.E. Brazil (Maceió) began mass culturing them by the thousands and by 1976 produced and released three million *A. flavipes*; and the parasitism of the borer in the field has been steadily rising (Saul H. Risco 1977).

According to Gallo *et al.* 1977) control of *Diatraea* spp. became a reality in the north and northeast of Brazil, mainly utilizing *Lixophaga diatraeae* and *Apanteles flavipes*, and in the south and southeast of Brazil control has come from the tachinids *M. minense* and *P. claripalpis*.

**Gelechiidae**

- *Platyedra gossypiella* (Saund.) - Cotton, etc.

Found in all continents. Some entomologists believe Australia may be its origin. Thompson (1946) lists 65 parasites of the pink boll worm in the world. Silva *et al.* (1968) lists 16 parasites being in Brasil with *Chelonus liber* Muesebeck being the most important. Presently in California where the pest has recently become established there is an active search abroad for natural enemies by Univ. of Calif., Riverside. Costa Lima (1953) discusses the use of certain *Bracon* spp.

- *Sitotroga cerealella* (Oliv.) - Stored grain

Cosmopolitan.

**Grapholitidae**

- *Carpocapsa* (=*Laspeyresia*) *pomonella* (L.) - Apples, pears, *Prunus*

Widely spread in temperate regions of the world. Origin probably in Russia or Asia. The biological control of this pest thus far has been poor. Recently there are new attempts being made (MacPhee *et al.* 1976).

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- *Grapholita molesta* (Busk) - Peach

Apparently originated in Asia. It is a major pest in Japan, Europe, USA, Canada, Brasil and Argentina. Attempts have been made in Argentina to control this pest by introducing parasites. The braconids *Macrocentrus ancylivorous* Rohwer and *M. delicatus* Cresson, *Ascogaster quadridentata*, *Bassus diversus* Muesebeck and the ichneumenia *Glypta rufiscutellans* Cresson were imported. *Macrocentrus delicatus* replaced *M. ancylivorous* in the Paraná Delta of Argentina (Crouzel 1963). In 1944 *M. ancylivorous* was introduced into Brazil and apparently became established (Gomes 1962). Further exploration for parasites on the mainland of Asia is recommended by MacPhee *et al.* (1976).

**Lyonetiidae**

- *Bucculatrix thurberiella* Busk - Cotton

In the southwest of USA, its outbreaks on cotton are correlated with insecticide applications. The nine parasites and ten predators recorded on it in Arizona and California naturally control it (Rejesus and Reynolds 1970).

- *Perileucoptera coffeella* (Guerin-Méni) - Coffee

Apparently a Neotropical species, but where did it originate? And from what host? Since coffee was introduced into Brazil. The Antilles may be its origin.

**Noctuidae**

- *Agrotis ipsilon* (Rott.) - Truck and forage crops

Cosmopolitan. Thompson (1944) lists 28 parasites associated with this pest in the world. Silva *et al.* 1968) records none occurring in Brazil.

- *Heliothis virescens* (F.) - Cotton, sugar cane, tobacco

In all the Americas. The ichneumonid *Campoletis peristinctus* Vierck, the braconid *Cardiochiles nigripes* Vierck, and *Polistes* wasps control *H. virescens* infesting tobacco in eastern USA (Rabb 1971). *C. peristinctus* is recorded to be in Uruguay (Silva *et al.* 1968).

- *Heliothis zea* (Boddie) - Alfalfa, corn, cotton, soya, tomato, etc.

Originally a new world species. In the southeastern USA at times *H. zea* is controlled

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by epizootics of a *Spicaria* fungus, and is also parasitized by *C. peristinctus* (Rabb 1971). In western USA *H. zea* is only a pest in cotton when insecticides disrupt general predators which prey upon it (Van den Bosch *et al.* 1971). Thompson (1946) lists 85 parasites under the species name of *H. armigera* which includes *H. zea*. In Brazil six parasites are recorded Silva *et al.* (1968).

- *Spodoptera litura* (F.) - Mango

Widely distributed in Australian and oriental regions and eastwards to the Pacific Islands (Browne 1968), and now apparently in Brazil (Silva *et al.* 1968), but Nakano *et al.* (1977) do not include it in their list of pests.

- *Pseudaletia adultera* (Schaus) - Rice, wheat

Occurs in India, Indochina, Java, Formosa, Philippine Islands, Australia, Fiji, Hawaii, USA, Mexico, Cuba, Guiana, Brazil, Argentina, and Uruguay (Guagliumi 1973). Silva *et al.* (1968) list many parasites occurring in Uruguay but apparently none have been recorded in Brazil.

**Phycitidae**

- *Anagasta kuehniella* (Zell.) - Stored grains

Cosmopolitan. Evidently its common parasite *Venturia canescens* (Grav.) arrived with its host in Brazil.

- *Paramyelois transitella* (Walker) - Fruits and nuts

Apparently a new world species. A new species of polyembrionic encyrtid found in Mexico by L. Caltagirone is now being mass cultured and periodically released in California's almond orchards.

- *Plodia interpunctella* (Huebner) - Stored grains

Cosmopolitan.

**Plutellidae**

- *Plutella maculipennis* (Curtis) - Crucifers

A Paleartic species which is now widely distributed in the world. The ichneumonid *Angitia cerophaga* (Grav.) introduced from England to New Zealand resulted in substantial control, and later from New Zealand to Australia accounted for partial control (DeBach 1964). Thompson (1946) lists 43 parasites.

## ORTHOPTERA

The few attempts to introduce natural enemies against grasshoppers and locusts have essentially failed. Greathead's (1963) world review of the natural enemies of grasshoppers and locusts lists 223 species of Acridoidea. and 534 species of parasites and predators.

**Gryllidae**

- *Gayllus assimilis* (F.) - Cotton, fruit trees, rice, potato, etc.

Cosmopolitan, but probably originated outside of Brazil.

## BLATTARIA

**Blattidae**

- *Periplaneta australasiae* (F.) - Stored food pest

Cosmopolitan. Introduced in Brazil.

**Epilampridae**

- Blatella germanica (L.) - Stored food pest

Cosmopolitan. Periodic releases of the elophid *Tetraschus hagenowii* (Ratz) has reduced this pest in Texas (Franke 1977).

- *Supella supellectilium* (Serv.) - Stored food pest

Cosmopolitan. *Comperia merceti* (Compere) is reported by Silva *et al.* (1968) to parasitiza *B. germanica* in Brazil. In Hawaii and California, it attacks the eggs of *S. supellectilium*.

**THYSANOPTERA**

The one known attempt to introduce an exotic parasite into a new country against a thrips succeeded in establishing the eulophid *Goetheana* (=*Dasycaphus*) *parvipennis* (Gahan) in Trinidad, Jamaica and Puerto Rico and apparently spread to Venezuela. The parasite was introduced from Ghana where it attacked *Selenothrips rubrocinctus* on cocoa but it is also known to attack *Thrips tabaci* in Java. Although it became established, several entomologists believed no economic control of *S. rubrocinctus* resulted from the introductions. It has also been found parasitizing *Heliothrips haemorrhoidalis* (Bouché) and *Hercothrips insularis* Hood in the field (Entwistle 1972).

Some species of Anthocoridae are important predators of thrips. In California *Orius tristicolor* (White) not only preys on thrips but also feeds on noctuid eggs and spider mites in alfalfa and cotton as well as some fruit trees. In eastern USA *O. insidiosus* (Say) has similar habits. There is one reference to an *Orius* sp. occurring in Brazil (Silva *et al.* 1968).

The mirid genus *Termatophylidea* is comprised of a few species found from Mexico into northern South America and to some, at least, West Indian Islands. One species in Mexico and another in Surinam have been observed to feed on the cocoa thrips, *S. rubrocinctus* (Entwistle 1972).

**PEST THRIPS SUSPECTED TO BE INTRODUCED INTO BRAZIL**

- *Caliothrips fasciatus* (Pergande) - Bean, cotton, citrus, etc.

In southern California, the bean thrips is parasitized by the eulophid *Thripoctonus russelli* Crawford.

- *Caliothrips femoralis* (Reuter) - Cotton, *Ficus*, Tomato, etc.

Wide spread in Americas.

- *Franklinella californica* Moulton - Alfalfa, emlon, tomato, etc.

In all Americas, but only southern Brazil

- *Frankliniella insularis* (Franklin) - Avocado, citrus, coffee, etc.

Wide spread in Americas but only in southern Brazil.

- *Frankliniella occidentalis* (Pergande) - Alfalfa, citrus, potato, Rosaceae, tomato

In all Americas, but only in southern Brazil.

- *Frankliniella tritici* Fitch - Wheat, omnivorus

In all Americas, but only in southern Brazil.

- *Gynalkothrips ficorum* (Marcha) - *Ficus* spp.

Apparently an introduced species to Brazil. The parasite *Tetrastichus tripophonus* Waterston, the anthocorids *Macrotracheleliella laerus*

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Champion and an *Orius* sp., and the syrphid *Baccha livida* Schin. were found attacking *G. ficorum* in Rio de Janeiro (Ribeiro 1962, Silva 1962). Near Recife, Carvalho *et al.* (1969) observed the syrphid and a pyemotid mite *Adactylidium beeri* feeding on the thrips. Since neither parasites nor anthoconids were observed near Recife, perhaps these natural enemies could be collected in the Rio area and released in Recife.

- *Heliothrips haemorrhoidalis* Bouché - Citrus, coffee, eucalyptus, mango, etc.

A very widely distributed species mainly in warm climates, nearly cosmopolitan.

- *Selenothrips rubrocinctus* (Giard.) - Cocoa, coffee, cotton, etc.

Very widely distributed in the tropics. It is an important pest of cocoa and it has been on this crop where activities of its natural enemies have been studied including the importation of a parasite (Entwistle 1972). See above introduction. In Brazil, Silva *et al.* (1968) report two predaceous thrips *Franklinothrips vespiformis* and a *Selenothrips* sp.

- *Taeniothrips inconsequens* (Uzel) - Pear, *Prunus* spp., etc.

Originated from Europe now widespread in temperate zones of the world. In Brazil found in Rio Grande do Sul.

- *Taeniothrips simplex* (Morrison) - Gladiola, Santa Rita palm.

Probably originated from where gladiolus come from.

- *Thrips tabaci* Lindeman - Cotton, onion, tobacco, tomato, etc.

Very wide spread in old and new world. In Japan it is parasitized by *Thripoctonus brui* Vuillet (Sakimura 1937)

**Adenda**

- *Opogona* sp. (Lepidoptera: Oinophilidae) - Bananas

Newly introduced into Brazil.

To apply the classical biological control method involves (

1. **Foreign exploration,**
2. **Quarantine testing,**
3. **Mass culture,**
4. **Release and establishment, and**
5. **Evaluation of natural enemy impact. (DeBach 1964, Huffaker and Messenger 1976).**

**(1) Foreign exploration** for natural enemies has not been practiced much by Brazilians. In the early biological control campaign against the coffee borer during the early 1930's two Brazilian entomologists went to Africa and shipped two parasites back to Brazil. The other species of natural enemies introduced into Brazil came as pure stocks from foreign biological control laboratories.

In the **future** Brazil should have one or two entomological foreign explorers who have some knowledge of taxonomy and biologies of entomophagous insects. When not on foreign assignment they can either work on taxonomic problems or conduct research on biologies of entomophagous arthropods.

At times exploration for natural enemies may be within Brazil itself. In a large country like Brazil, there can be pests that inadvertently have been moved from one area to new areas without their natural enemies, or search can be made for parasites or predators that may attack related species of pests that are isolated from pest species. For example, the Amazon fly which was found attacking a related species of the sugar cane borer which was feeding on a graminae plant host in the Amazon region and this tachinid fly parasitizes the *Diatraea saccharalis* and *D. flavipennella* Box. Or like cocoa which is grown near the cost in a strip of rain forest is ecologically isolated from the great Amazon basin by a vast savana. The cocoa is completely isolated from its native pests. This is good from the aspect of pest isolation, but should a pest be accidentally introduced from the Amazon area and leave its natural enemies behind, it would be necessary to explore the Amazon area for its natural enemies. This may be the case of the giant borer of sugar cane, *Castnia licus* which conceiveably originated in the Amazon region leaving its natural enemies behind. The cocoa research lab in San Salvador keeps all cocoa, plants under quarantine when coming from either the Amazon area or abroad to insure that no diseases or other pests are introduced into the commercial growing areas of Brazil when the cocoa is transplanted.

Furthermore, just because a pest is considered of neotropical origin does not mean it originated in Brazil because it occurs in Brazil today. There are pests today in Brazil that are considered native because they are neotropical and possess some parasites. Having parasites associated with a host usually is an indicator of the host being in its endemic area, but look at the Rhodes grass scale which originally came from Asia, and has had an exotic parasite from India established against it in Brazil yet two native primary parasites and one hyperparasite have been found in Brazil attacking it.

Foreign explorers in search for natural enemies must keep in mind to collect in areas similar to the climatic area where the pest occurs in Brazil, and if the same species of parasite is found in different climatic zones in its native land, the different biotypes should be kept separate in shipments and cultured separately until released and released in similar climatic zones in Brazil to the ones where the parasite originated.

**(2) Quarantine** testing is an obligatory step if mixed or unknown parasites are in shipments

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received in a new country. To conduct classical biological control the natural enemies must be tested under quarantine conditions to determine if they are truly primary parasites before they can be released. Thus pure, uncontaminated target pest organisms only are exposed to incoming exotic parasites. If the natural enemies fully develop under these conditions, they then can be mass cultured and released. With parasitic insects, the quarantine test usually only requires going through one generation; insect predators may require two generations, and phytophagous insects being considered for importation to control weeds may require years of testing to determine their host range. Usually such phytophagous insects are tested in the country where they were collected.

Brazil does not apparently have any quarantine facilities for screening biological control materials, and this greatly limits Brazil's classical biological control capability. Today Brazil must rely on foreign countries that have already tested parasites or predators under quarantine and can only receive pure stocks of natural enemies. This is fine and this was the manner that the Cuban fly and *Apanteles flavipes* were obtained for control of the sugar cane borer and eight other natural enemies of other pests were handled in this manner but in the **future** should Brazil desire to do independent classical biological control, it is imperative that at least one quarantine facility be established in Brazil. Ideally, four quarantine centers are needed and could be located at the following universities: UFRGS, at Porto Alegre; ESALQ, at Piracicaba; UFRRJ, at Rio de Janeiro, 47 km and UFRP, at Recife. The University of Lavras in Minas Gerais State already has a quarantine facility planned in one of their new buildings which is about to be constructed. The type of quarantine construction necessary are presented by Peracchi (1962), DeBach (1964) and in proposed biological center by Gallo *et al.* in 1971.

There should be one institution preferably at the Federal level responsible for issuing shipping permits. Perhaps a three san committee a biological specialist, a taxonomist and an economic entomologist should approve or disapprove giving permission for shipping in new biological control material. Each quarantine center should be requested to provide at least an annual report on the material it receives and the natural enemies released including where and when released. Also some specimens of the exotic material received should be preserved at the quarantine center and at the nearest Economic Taxonomic Center.

**(3) (4) Mass culture and release**. After clearing quarantine testing, the natural enemies are passed to an insectary operation to increase the numbers of natural enemies for release. The insectaries should be near the quarantine facility and can be headed by the same person in charge of quarantine. For some parasites it is necessary to culture them on plant hosts that have to be grown in a greenhouse; thus, ideally there should be a glasshouse nearby the insectary. In recent years often factitious hosts (unnatural hosts) can be used if the parasite will develop completely on such hosts. Furthermore, if the factitious host or true host can be reared on artificial diets, the insectary staff is freed from growing plants. This has been done in Brazil for culturing some of the tachinid fly parasites of the sugar cane borer. Gallo and Berti (1975) of ESALQ found that certain tachinids parasites of the sugar cane borer could be cultured on the wax moth which in turn could be cultured on inexpensive artificial diets, and this technology has been adopted by the insectaries of COPERSUCAR Co. and PLANALSUCAR who have been mass culturing some species of tachinids for release in sugar cane fields with success to control the sugar cane borer (Gallo *et al.* 1977, Risco 1977). On the other hand, the more specific parasite *Apanteles flavipes* must be cultured directly on the sugar cane borer, however, the sugar cane borer is cultured on artificial diet.

The fungus *Metarrhizium anisopliae* is also being mass cultured on prepared media by PLANALSUCAR and COPERSUCAR Co. for application in sugar cane fields to control cercopid pests (Guagliumi *et al.* 1974). Furthermore there is support in a national program to develop new strains and test other fungi for insect control at the University of Campinas.

The researchers of Brazil are up-to-date in their approaches and techniques of mass culturing pest insects as well as diverse groups of parasites and fungi. Therefore, in the **future** it is visualized that the Brazilians are quite capable in this area and there are students today in some of the Brazilian universities working on insect nutrition.

Releases of the first lots of new parasites in a new country should be done in small areas but in different environmental zones to attempt to fit the natural enemy into an environment similar to where it was collected. Once the parasites have become established in its new environment, then they can be distributed over broader areas as they become available.

When a natural enemy has become established the biological research center can turn the cultures over to State Departments of Agriculture or private companies should periodic colonization of the natural enemy be required for further distribution. The University should not become a service organization of continually mass culturing natural enemies for the public use.

**(5) Evaluation** in cases where obvious reduction of the pest population occurs within three years or three generations of pest after establishing a natural enemy (Clausen 1951) it may not seem necessary, but critics will explain the reduction as result of other factors than natural enemies. Furthermore, the role of the established natural enemies in the population dynamics of pest should be published and made locally public so that any use of pesticides on the crop where the natural enemies are active are not destroyed.

For a proper evaluation of the impact of a newly introduced natural enemy, it is necessary to sample populations of the pest for existing natural enemies before any releases of parasites or predators are made in order to establish a base line of the pest population's average density over several generations. Furthermore, general surveys of pests should be made to determine what natural enemies are associated with Brazilian pests and there should be an on-going project of biological control workers to make known to pest managers of crops and forest the existence of important natural enemies. The impact of predators is more difficult to determine than parasites or pathogens which usually leave obvious signs of their presence. At the CENA Institute of ESALQ, Piracicaba, researchers are using p32 to label sugar cane and its pests to determine what predators are active in the sugar cane ecosystem. Critical to evaluating the impact of natural enemies is having some knowledge of economic injury level of the pest, and in Brazil there is some research along these lines in several universities that were visited.

In the **future**, we visualize no problems in Brazil of trained entomologists performing proper evaluation techniques if given support. For further details on evaluation methods see: Kogan 1962, DeBach 1964, and Huffaker and Messenger 1976.

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## AUGMENTATION

At times it is necessary to increase the effectiveness of natural occurring parasites, predators or pathogens against certain pests in certain crops. There are two main approaches used if the natural enemies are not effective: (1) periodic releases of natural enemies, and (2) manipulating the environment. In Brazil the first method has been employed.

**(1) Periodic releases** of natural enemies usually requires the ability to mass culture the biotic agents. In Brazil two or three species of tachnids, *Apanteles flavipes*, and the fungus *Metarchizium anisopliae* are mass cultured and released or sprayed in fields where it has been determined to be necessary.

In Brazil, PLANALSUCAR (a national program concerned with the improvement of sugar cane varieties, nutrition, irrigation and the control of diseases, insects and weeds), and COPERSUCAR (a cooperative of sugar mill companies) have adopted the mass culture techniques developed at BSAIQ, USP, Piracicaba for culturing tachnids as mentioned earlier.

PLANALSUCAR´s sugar cane fields in Alagoas State are monitored regularly checking on population abundance of at least seven different insect pests. Fifteen persons monitor pests in 257,320 hectares of sugar cane. Thus, one person covers 17,154 hectares, and where necessary releases of parasites are made against the sugar cane borer and/or the fungus is applied against the cercopids (Risco 1977). This operation is to be commended.

The necessity to make periodic releases is because of disruption by harvesting which disengages natural enemies from the sugar cane eco-system, furthermore, the vastness of the monoculture provides little refuge and no alternate hosts to sustain natural enemies in higher numbers, and if pesticides are used which could eliminate natural enemies, releases of natural enemies is called for.

Mass culture of a *Trichogramma*, an egg parasite of a butterfly, *Eucelasia Riodinidae* (see in foregoing list) which attacks eucalyptus is being carried out between the UFMG university at Belo Horizonte and a private company growing huge forests of eucalyptus. In this case releases of *Trichogramma* are not made regularly and are made only if an impending outbreak of the pest butterfly is anticipated.

There is the possibility of augmenting egg parasites by spraying irradiated eggs or normal eggs of an insect that does not attack the plants where released. The added eggs to the environment could be used by natural occurring egg parasites when their natural host eggs are scarce.

In the **future**, Brazil may become the leading country in the use of periodic releases of natural enemies for the entomologists in Brazil have already demonstrated this in sugar cane fields.

**(2) Manipulating the environment** to increase the effectiveness of natural enemies includes use of alternative hosts, providing natural or artificial food, application of behavioral chemicals and the use of artificial shelters (Hagen and Hale 1974, Rabb *et al.* 1976). In Brazil, little has been done along these lines, in fact these types of environmental modifications are rather recent developments in the field of biological control and are not yet practiced widely in any country.

As ecological requirements and behavior of natural enemies are determined, obvious deficiencies in crop environments at times are revealed, and it may be possible to correct the deficiency artificially.

Alternative hosts can be added as indicated above by placing unnatural eggs in a crop to increase egg parasites, or by purposefully leaving part of the crop standing while most of it is harvested or actually plant small plots of host plants to support alternative hosts.

Providing artificial food in the field for retaining and attracting certain predators and even stimulating oviposition has been demonstrated. *Chrysopa carnea* Stephens, a common effective predator as a larva, in the adult stage is mainly a honeydew feeder. Thus by spraying artificial honeydew that contains an attractant (Kuiromone) it was not only possible to attract many *Chrysopa* adults but when they fed on the protein containing food they deposited eggs in the field far below the densities of pests that normally would induce oviposition (Hagen *et al.* 1970). The use of behavioral chemicals such as kairomones (interspecific communication chemicals that benefit the receiving organism) makes it possible to influence oviposition in unnatural hosts (Lewis *et al.* 1976).

Providing artificial shelters or breeding sites for predators has been used in a small scale in the USA. Wooden boxes on stakes at edges of crops have encouraged predatory wasps to build nests and the wasps enter the crops to capture moth larvae to feed their young. Paulo Cassino of UFRJ near Rio de Janeiro will use this technique in his Ph.D. thesis dissertation.

In the **future**, Brazil with its present students being trained with an ecological background have the basis of carrying out or developing methods of modifying the environment to benefit natural enemies or hinder development of pest populations.

## CONSERVATION

Conservation of natural enemies deals mostly with integrating biological control with chemical control (Stern *et al.* 1958, Hagen and Smith 1959, Corbet and Smith 1976). If pesticides are required in a crop, its selectivity, its dosage and its timing are important considerations before applying any pesticide. The control programs employed by the large sugar cane plantations (PLANALSUCAR, COPERSUCAR) have truly become models of integrated pest management to be emulated not only by other agriculture crop producers in Brazil but also by pest managers in other countries. Pesticides, particularly insecticides are used at a minimum and ones used like the fungus *Metarrhizium* to control cercopids not only spares the natural enemies of the cercopids but also those of other pests particularly the parasites of the sugar cane borer.

There is much interest in the research development and use of fungi to control insects in Brazil, and in the climate of Brazil fungi offer a great **future** as selective pesticides.

In other crops and forests various commercially produced *Bacillus thurigensis* products are being tested against various pests, and this is to be encouraged because their pathogens are fairly selective and will conserve natural enemies in crops where it is applied.

In the **future**, Brazil will lead the way in many crops using the integrated control approach and will be world leader in use of fungi to control insects, as well as other insect pathogens, only the viruses remain to be used.

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*Some citations in the original text did not have the appropriate references, which is why they are not included in this item.

[2]**Kenneth Sverre Hagen**. Emeritus Professor of Entomology in the University of California at Berkeley in the USA, K. S. Hagen (1919-1997) is one of the worldwide entomologists. He developed researches on the integrate insect's management focusing the application of natural predators and parasites in the agricultural control. Among hundreds of his contributions to Science he developed the first insect egg in laboratory for the rearing of *Chrysoperla* (Neuroptera) besides diets to rear Coccinellidae. Both importants for Biological Strategies. He was member of the main Scientifics Societies of the USA. Also his work was recognized by the International Organization of Biological Control giving him the Distinguished Biological Control Science Award.

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