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THE BIOLOGICAL CONTROL OF SUGAR CANE, VEGETABLE AND OTHER CROP PESTS IN BARBADOS AND THE EASTERN CARIBBEAN ISLANDS

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ABSTRACT

Biological control of insect pests in the Caribbean dates back to the early 1900 s. In spite of many failures, several parasites and predators have been successfully established in Barbados and the Eastern Caribbean Islands, for the control of crop pests. Some have provided complete control, while the others have reduced the pest populations considerably and have paved the way for further introductions, and ultimately the economic control of those pests.

In 1974 the biological control of insect pests of horticultural crops in Barbados was reported. Since then a number of other natural enemies were established in Barbados and the Eastern Caribbean islands.

This paper discusses the biological control of the major pests of sugar cane and of some commonly grown crucifers, cucurbits and vegetable crops in the Eastern Caribbean.

RESUMEN

El control biológico de insectos plaga, en el Caribe se llevó a cabo desde los años 1900, en las islas de Barbados y en las del Caribe Oriental. A pesar de muchos fracasos, exsiste un gran número de parásitos y predatores, los cuales se han establecido con gran éxito para la represión de plagas en los cultivos. Algunos de ellos ofrecen un control completo, minetras que los otros han abierto el comino para nuevas introducciones y con miras ultimamente de obtener un control económico de dichas plagas.

En la isla de Barbados en el año 1974, se anunció el control de insectos plaga en los cultivos horticolas. Desde entonces un número de otros enemigos naturales se establecieron en la isla de Barbados y en las islas del Caribe Oriental.

En esta presentación discutiremos el control biológico de algunas de las mas importantes plagas de la caña de azucar y de algunos cultivos comunes, como ser, los crucíferos, cucurbitos y hortalizas, en las islas del Caribe Oriental.

The use of natural enemies for the control of insect pests on sugarcane, vegetables and other crops in the Caribbean has a long history. Investigations on biological control of insect pests in Trinidad and Tobago dates back to the early part of the century, when, following outbreaks of sugarcane froghoppers in 1906–1908, an entomologist, Mr. F.W. Urich, was appointed and Dr. L.W. Gough from England was brought to Trinidad to study the problem. After preliminary investigations, the Reduviid bug *(Castolus plagiaticollis)*, a predator of froghopper in Mexico, was introduced in 1911 (Bennett, 1975). The work continued for several years, with some unsuccessful attempts being made to augment the indigenous natural enemies, viz., egg-parasites, predators (Syrphids) and the Green Muscardine Fungus *(Metarrhizium anisopliae* (Metch.)*)*.

In 1928, J.G. Myers, an entomologist from the parasite laboratory of the Imperial Institute of Entomology, at Farnham Royal (now the Commonwealth Institute of Biological Control, CIBC), arrived in the West Indies to explore the possibilities of biological control of insect pests: he provided valuable information on the major insect pests and their natural enemies (Myers, 1931). The Amazon fly *(Metagonistylum minense* Tns.*)* was discovered and introduced by Myers into Guyana, and provided excellent control of the sugarcane mothborer *(Diatraea saccharalis* (F.)*)*. Subsequently the parasite was introduced and established in St. Lucia, Guadeloupe and Venezuela, but it failed to establish in Trinidad.

Barbados, which is well known for its sustained efforts for the biological control of sugarcane and other crop pests, started an organized biological control programme against sugarcane moth-borer in 1927 under the direction of R.W.E. Tucker. This was continued by other entomologists and remains a very viable programme.

Tucker (1936 and 1954) reported the introduction and establishment of various natural enemies against sugarcane moth-borer, sugarcane root-borer *(Diaprepes abbreviatus* (L.)*)* and white-grub *(Phyllophaga (=Clemora) smithi* (Arrow)*)* on sugarcane; the pink bollworm *(Pectinophora gossypiella* (Saund.)*)* and a leaf defoliator *(Anomis (=Alabama) argillaceae* (Hub.)*)* on cotton; cottony cushion scale *(Icerya purchasi* (Mask.) on citrus, pigeon pea and other plants; cabbage white butterfly *(Ascia monuste monuste* (L.)*)* on cabbage; coconut scale *(Aspidiotus destructor* Sign.*)* and white fly *(Aleurodicus cocois* Curt.*)* on coconut; and against the house fly *(Musca domestica* L.*)*.

Between 1964 and 1984, a large number of natural enemies were introduced into Barbados against various pests, from different parts of the world, and those which were successfully established were subsequently introduced into the Windward and Leeward Islands.

Some of the insect pests against which natural enemies were introduced are discussed below:

Sugar-cane Pests and their Natural Enemies

Sugar-cane Moth-borers *(Diatraea saccharalis* (F.)*)*

Diatraea saccharalis is present in all sugar-cane growing countries in the region, causing substantial crop losses. In Barbados, between 1963 and 1966, the average sugar loss due to the moth-borer damage was 13,911 tons per year (Alam *et al*, 1971). *Diatraea centrella* is another important pest of sugar-cane in the Caribbean, and has been reported from Trinidad, St. Vincent, St. Lucia, Grenada, Guyana and Suriname, causing heavy crop losses. In Guyana where *D. saccharalis* was successfully controlled by the introduction of Amazon fly *(Metagonistylum minense* Tns.*)*, *D. centrella,* which is relatively resistant to the

attack of this parasite, became a major pest and accounts for more than 90 per cent of the borer damage (Bennett, 1969).

Because of the perennial nature of the crop, the overlapping generations of the pest throughout the year, and a number of alternate host plants present in and around the sugar-cane fields, chemical control has not been considered suitable in the West Indies.

In most of the Caribbean islands, and particularly in Barbados, efforts have been concentrated on biological control for the pest. A regular biological control programme against *D. saccharalis* was started in 1927, when the indigenous egg-parasite, *Trichogramma exiguum* Pinto and Platner *(=T. fasciatum* auct. = *T. minutum* auct.*)*, along with a number of strains or species imported from various Caribbean islands, were mass-bred in the laboratory and released in sugar-cane fields annually for some 32 years. Initially, the campaign was considered to be a success. Between 1930 and 1934, the percentage of joints bored was reduced from about 33% to about 15%. During 1959, when the parasite releases were stopped, there was no increase in the moth-borer damage, suggesting that the parasite had attained its maximum potential and was not able to further reduce crop damage.

Between the 1930 s and the 1960 s, a number of egg, larval and pupal parasites were introduced from India, Pakistan, Uganda (East Africa) and the Caribbean (Alam *et al.*, 1971). Of these, two larval parasites, *Cotesia (=Apanteles) flavipes* (Cam.) from India and *Lixophaga diatraeae* (Tns.) from the Caribbean, became established and provided excellent control (Alam *et al.*, 1971 and Alam, 1980). Since 1968, the percentages of joints bored have decreased significantly, and have remained below 5% (the level at which no further control measures are required), except in 1974–75 when it increased slightly.

Since 1968, Barbados has earned an added revenue from sugar of B'ds $1,026,300 to 7,214,400, averaging $2,573,870 per year, from the reduction in damage and losses. The great variations in additional earnings have been due to variations in the commodity price and to the size of the crop.

In St. Vincent, sugar-cane was planted on some 2,000 acres in the 1950's, but cultivation ceased in 1962. In 1975, the crop was re-introduced and at present (1985) some 1,500 acres are under sugarcane. Between 1975 and 1978, some 75 acres of sugarcane were planted at four different localities. The canes were heavily attacked by *D. saccharalis* and *D. centrella*. A survey conducted during February and May 1978, revealed some 75% of stalks and 53% of joints bored.

In February 1978, some 650 adults of *C. (=A.) flavipes* were carried from Barbados and released in a 58 acre plot on the Windward side of the island. The first parasite recovery was made in May 1978, when 31.6% *Diatraea* larvae were parasitised. To augment the existing parasite population and hasten its spread, a further 600 *Cotesia* adults from Barbados were liberated.

Since 1978, with expansion of the acreage under sugarcane, the parasite has also spread and maintained high levels of parasitism, ranging from 24% to 73%, depending on the time of the year.

In May 1985, when the young (plant and ratoon fields) and mature cane fields were surveyed, it was found that *D. centrella* was more abundant in young cane fields, while *D. saccharalis* was more prevalent in mature cane fields. The most important observation made was that, although *C. flavipes* is generally considered to prefer *D. saccharalis* larvae elsewhere, it was more abundant on *D. centrella* larvae, which are generally regarded to be resistant to this and other parasites (Beg and Bennett, 1974). The field parasitism levels for the two species were 13 to 33% for *D. saccharalis* and 67 to 100% for *D. centrella*.

Since the establishment of *C. flavipes* and the increase of the populations of the indigenous natural enemies, particularly the egg-parasites, *T. exiguum* and *Telenomus alecto* Crawford, along with some other biotic (predators and pathogens) and abiotic (wind, water/rain) factors, the moth-borer populations in St. Vincent have been reduced below the economic level of 5%. Between 1978 and 1984, the average levels of joints bored were: 53% in 1978, 19% in 1979, 29% in 1980, 15% in 1981, 8% in 1982, 5% in 1983 and 3% in 1984.

Based on the 1981 total of approximately 1,500 acres of sugarcane, and an average joint infestation of 15%, the Sugar Industry lost about 400 tons of sugar (based on 1.8 tons of sugar/acre, and 0.5% loss of sucrose for every 1% joints bored) during that year. However, during 1984, these losses were reduced to about 67 tons of sugar, which is indeed a substantial saving!

In St. Kitts, Yaseen (1979) reviewed the status of the moth-borer, *D. saccharalis* and its control by the Cuban fly, *Lixophaga diatraeae* (Tns.), and the factors responsible for the increase in the pest populations, which were due mainly to changes in cane varieties, cultural practices and weather conditions. Because of the general increase in the pest populations, the Commonwealth Institute of Biological Control (CIBC) recommended, in the early 1970's, the introduction of another larval parasite, *C. (=A.) flavipes* from Barbados. The parasite was successfully established and provided additional control of the pest. In 1979, the Caribbean Agricultural Research and Development Institute (CARDI) assumed the responsibility for monitoring the pest/parasite situation in St. Kitts, and further releases of *C. flavipes* were made. During the period 1981 to 1984, joint infestation surveys conducted in the island showed that the pest population never exceeded the critical level of 5%. Average annual joint infestation ranged from 2.2 to 3.4%. The two larval parasites, *C. flavipes* and *L. diatraeae*, were consistently recorded in cane fields, although populations were low, mainly due to low host density.

C. flavipes was also successfully introduced into Jamaica and Trinidad (mainly through CIBC, Trinidad), where, along with some indigenous natural enemies, it had provided good control. In Trinidad, during 1980 and 1981, the range of parasitism on *D. saccharalis* was 50–90% (des Vignes, 1985). In Jamaica, between 1980 and 1984, the indigenous larval parasites, *L. diatraeae* and *Agathis stigmaterus* (Cresson), attacked on average of 21% *D. saccharalis* larvae, whereas, during the same period, the parasitism by *C. flavipes* ranged from 0–50% in individual fields. The combined level of parasitism rose from 21% by *Lixophaga* and *Agathis*, to 34% in fields where *Cotesia* was introduced (Falloon, 1985).

Sugar-cane Mealybug *(Saccharicoccus sacchari* (CKll.)*)*

This pest is widely distributed in sugar-cane growing countries throughout the World. In the Caribbean, the pest is distributed in both the Greater and Lesser

Antilles. In Barbados, although generally it has not been a serious pest, it has caused considerable damage in low rainfall areas, particularly during long, dry spells, and damage was more pronounced when associated with moth-borer attack. Although a few indigenous natural enemies were found, their populations were too low to substantially reduce the mealybug infestation.

During the 1970 s an Encyrtid parasite, *Anagyrus saccharicola* Timb. from Uganda (East Africa), was successfully introduced and established in Barbados. Since then the parasite has reduced the pest population by over 90% in the field, and has kept it under excellent control.

A. saccharicola was also introduced into St. Vincent and St. Kitts, where it quickly became established and has provided good control. In the 1970 s, at the request of the Sugar Industries in Guyana and Jamaica, the parasite was supplied from Barbados. Initial recoveries from Guyana were reported by the entomologist from GUYSUCO, but the present status in both countries is not known.

Sugar-cane Root-borer *(Diaprepes abbreviatus* (L.)*)* and Brown Hard-back *(Phyllophaga* (=Clemora) *smithi* (Arrow)*)*

Both these pests are known to have attacked sugar-cane in Barbados for almost 100 years. Usually, after long droughts, the pest appears in epidemic proportions causing heavy crop losses. Fennah (1976, pers. comm.) stated that "this may be due to the fact that an unusually long drought prohibits the adults' emergence. When rain falls after such a drought a massive synchronous emergence occcurs, which swamps the natural control factors".

Tucker (1936) reported the introductions of *Tetrastichus haitiensis* Gahan, *Ufens osborni* Dozier and a *Horismenus* sp. from Puerto Rico and Haiti, against *D. abbreviatus; Campsomeris tricincta* (F.), *Campsomeris trifasciata* (F.), *Myzinum ephippium* (F.), *Myzinum haemorrhoidale* (F.) and *Myzinum xanthonotum* (Roh.), against brown hard-back; and *Ignelater (=Pyrophorus) luminosus* (Illiger) from Puerto Rico, and *Bufo marinus* (Gaint toad) from Guyana, against brown hard-back and root-borer. Of these, *I. (=P.) luminosus* and *B. marinus* became established.

During 1975–84 a number of egg-parasites, viz., *T. haitiensis, Tetrastichus gala* Walker (wrongly identified as *T. marylandensis* Gir.), from Jamaica; *Tetrastichus* spp., from St. Vincent and Montserrat and *Fidiobia citri* Ashmead and *Brachyufens (=Ufens) osborni* (Dozier) from Florida, were introduced against *D. abbreviatus.* All these parasites attack the host eggs when laid between citrus leaves, where these can easily penetrate with their ovipositors, but these parasites have not parasitised eggs laid on sugar-cane leaves, the tissues of which are much harder for these tiny wasps to penetrate with their ovipositors.

During 1984, an entomogenous nematode *(Neoaplectana glaseri)* was obtained from the United States Department of Agriculture (USDA) laboratory in Orlando, Florida, and is being multiplied in the laboratory in Barbados. From the small applications made in sugarcane fields, some recoveries were made. Further work is in progress.

Sugar-cane Jumping Borer *(Elasmopalpus lignosellus* (Zell.)*).*

The attack of sugar-cane jumping borer is usually associated with the pre-harvest burning of sugar-cane, but recently infestations were recorded in plant cane fields, where the trash cover was poor. In many Caribbean islands, viz., Trinidad, St. Vincent, Antigua. St. Kitts, Guadeloupe, Jamaica and the Bahamas, where pre-harvest burning is a regular practice, the young, germinating tillers are heavily attacked by the pest, producing miniature, dead hearts. However, in Guyana, in spite of widespread burning of sugarcane, jumping borer is not a problem. It seems that, in Guyana, the high moisture content in the fields (in many cases cane stumps are submerged in water), prevents the pest from laying its eggs at the base of germinating tillers.

In Barbados, the pest attacks 24–57% (average 36%) of young tillers. In low rainfall areas, particularly during long, dry spells, such fields become a total loss and need replanting (Alam and Gibbs, 1979).

In Barbados, two larval parasites, *Stomatomyia (=Plagiprospherysa) trinitatis* (Thompson) and *Eucelatoria australis* Townsend, attack some 40% of the pest population. An Ichneumonid, *Macrocentrus* sp., was introduced from Trinidad, but it did not become established (Alam and Gibbs, 1979). However, with the reduction in sugar-cane burning, jumping borer is no longer a serious problem in Barbados.

In Jamaica, where the pest is widespread, some eight parasite species attack the eggs and larvae in the field, and their overall parasitism was 7% in 1974 and 14% in 1975 (Falloon, 1978). Some of these natural enemies could be introduced where the sugar-cane jumping borer is a persistent problem.

Vegetable Crop Pests and their Natural Enemies

Crucifers (Cabbage, cauliflower, radish and other related crops)

In Barbados, some 20 insect species attack these crops. The pests of real economic importance are diamond-back moth *(Plutella xylostella* (L.)*),* cabbage white butterfly *(Ascia monuste monuste* (L.)*)* and cabbage semi-looper *(Trichoplusia ni* (Hubner)*).* In Trinidad, cabbage bud-worm *(Hellula phidilealis* (Walker)*)* also causes heavy economic losses.

In the Caribbean in general, and in Barbados in particular, a number of indigneous natural enemies have been recorded, but these do not provide adequate control. As a result, a number of exotic, natural enemies have been introduced from India, Pakistan and the Eastern Caribbean islands against these pests. Some of these have established in Barbados, and later in the other Caribbean islands, and have provided good control.

The Diamond-back Moth *(Plutella xylostella* (L.)*)*

Diamond-back moth is the most serious pest of cabbage, cauliflower and other related plants (Alam, 1982), causing heavy economic losses. In the entire Caribbean, a wide range of pesticides are used at short intervals to control the ravages of this prest, creating new ecological and biological problems. To reduce the dependence on chemical pesticides, a number of parasites obtained from the overseas were tried in Barbados. Of these, two species, (i.e. *Cotesia (=Apan-*

teles) plutellae (Kurdj.) from India and *Tetrastichus sokolowskii* Kurdj. from India, St. Vincent and Montserrat, W.I. have permanently established. More recently, *Diadegma eucerophaga* Horstmann, imported from Pakistan, showed early signs of establishment, but persistent applications of pesticides did not allow the parasite to establish permanently.

At present, *C. (=A.) plutellae* is widespread in Barbados. The estimated annual average range of parasitism between 1971 and 1984 was 18 to 56%. It has been successfully introduced into the Windward and Leeward islands. In Antigua, St. Kits and Nevis, up to 75% of *Plutella* larvae are parasitised.

T. sokolowskii, indigenous to the Eastern Caribbean islands, was also introduced into Barbados from India, St. Kitts and Montserrat. Following releases, it was recovered from many cabbage fields. The levels of parasitism recorded were: 68–100% (average 86%) in 1976; 26% in March and 13% in April, 1980; 9% in 1982 and only 1% in 1983. The great variations in parasitism levels over the years are possibly due to the persistent use of pesticides against various cabbage pests, to which this parasite is more prone, compared to *Cotesia*, which has apparently developed a certain degree of resistance to the common pesticides used in Barbados and the Eastern Caribbean islands.

Cabbage Semi-looper *(Trichoplusia ni* (Hubner)*)*

This is not normally a serious pest in Barbados, but occasionally it attains high populations, causing serious defoliation which necessitates the use of pesticides. During heavy infestations, the pest is attacked by a number of indigenous egg, larval and pupal parasites. A small percentage of eggs is attacked by a *Trichogramma* sp., *Cotesia (=Apanteles)* sp. prob. *plutellae* (Kurdj.) attacks about 17% of young larvae; *Glyptapanteles (=Apanteles)* sp. *(vitripennis* group), a gregarious larval parasite, attacks 0.5 to 2%, and *Euplectrus platyhypenae* How., a gregarious ecto-larval parasite, attacks 4 to 50% (Avg. 19%) of young to full-grown larvae. *Brachymeria* sp., a pupal parasite, was reared from 0.5% to field-collected pupae. Two Tachinid larval-pupal parasites, *Winthemia* sp. nr. *pinguis* Fab. and *Winthemia* sp. ? *pyrrhopyga* (Wied.), jointly attack 20 to 36% pest population.

An indigenous species of a polyembryonic, egg-larval parasite, *Copidosoma (=Litomastix)* sp. nr. *truncatellum* (Dalman), attacks 0.5 to 5% of the pest population. A related species of this polyembryonic parasite, *Copidosoma (=Litomastix)* sp. *(truncatellum* group*)*, was introduced from India. This parasite attacks an average of 26% of the semi-looper population on cabbage (Alam, 1982). The parasite has also been introduced into the Leeward and Windward islands.

Cabbage White Butterfly *(Ascia monuste monuste* (L.)*)*

Cabbage White Butterfly remains active throughout the year in Barbados, although, through the greater part of the year, its populations remain low. During the rainy season, it may reach outbreak proportions, when the number of larvae per plant range from 20 to 100, defoliating the plants completely. It is widely distributed in the Greater and Lesser Antilles, South and Central America, and in the U.S.A. It feeds on a large number of cultivated and wild plants (Alam, 1982).

During outbreaks, the pest is attacked by a number of parasites, predators and pathogens. A Tachinid, *Phorocera* sp. ? *parviteres* Aldr. attacks about 14% larvae; *Brachymeria ovata* Say. parasitises an average of 36% pupae on cabbage. A small percentage of eggs is attacked by a *Trichogramma* sp. During the rainy season, when the humidity is high, a Polyhedrosis virus kills some 20% full-grown larvae and 95% pupae.

In Barbados, Tucker (1936) reported the introduction of *Apanteles glomeratus* (L.), a larval parasite, and *Pteromalus puparum* L., a pupal parasite. Alam (1982) reported the introduction of two larval parasites, *Apanteles* sp. and *Horogenes* sp., and of a pupal parasite, *P. puparum* from Pakistan. *A. glomeratus* from Canada, successfully parasitised the *Ascia* larvae both in the laboratory and the field, and, after releases, a few field recoveries were made. However, the establishment was not permanent. *Apanteles* sp. (from Pakistan), although it stung young *Ascia* larvae when placed near them in the laboratory, never completed development.

P. puparum, from Canada and Pakistan, was successfully bred in the laboratory on *Ascia* pupae, and thousands of adults were liberated in heavily infested cabbage fields, but the parasite was never recovered (Tucker, 1936 and Alam, 1982).

In St. Kitts, a larval parasite, *Lespesia aletiae* (Riley) (Tachinidae), attacks some 50% of larvae, and a pupal parasite, *Brachymeria innulata* F. (Chalcididae), over 50% of pupae in the field. These are regarded as good canditates for further introductions into Barbados and the other Eastern Caribbean islands.

Cucurbits (Cucumber, pumpkin and squash)

Although these crops are attacked by a large number of pests, two are of major importance.

Melon-worm, *Diaphania (=Margaronia) hyalinata* (L.)

Melon-worm is the most important. In Barbados, the pest population on cucumber remains relatively small, varying from 0–16% (average 0.4%) larvae per leaf, whereas, on squash and other related species, the larval population is usually very high, causing serious defoliation. Fifteen to 25 larvae per leaf can easily be found.

The natural enemies recorded in Barbados are given in Table 1.

The populations of these parasites vary considerably throughout the year, and have little effect on the control of *Diaphania*. A pupal parasite, *Trichospilus diatraeae* C. & M., introduced from India, is now established in Barbados, and attacks 2 – 5% of pupae in the field.

In St. Vincent, a larval parasite, *Hypomicrogaster diaphaniae* (Mues.), attacks up to 75% of larvae in the field. A small number of adults raised in the laboratory were released in Barbados, but no recoveries were made. Because of its seasonal abundance in St. Vincent, it is worthwhile carrying out a comprehensive breeding and release programme in Barbados and other Eastern Caribbean islands where *Diaphania* is a serious pest.

Table 1. Average percentage parasitism recorded between 1980-84, by *Cotesia* (=*Apanteles*) sp. (*glomeratus* group), *Eiphosoma dentator* (F.), *Brachymeria* sp. and *Trichogramma pretiosum* Riley.

Year	Average percentage parasitism			
	C. (=*A.*) (*glomeratus* group)	*E. dentator*	*Brachymeria* sp.	*T. pretiosum*
1980	13.7	9.8	0.5	—
1981	7.9	4.7	—	—
1982	6.1	2.6	1.0	30.3
1983	10.2	2.4	2.5	51.5
1984	13.6	5.7		

Leaf-miner (*Liriomyza sativae* Blanchard (=*Liriomyza munda* (Frick))

Leaf-miner attacks some 16 vegetable crops and 35 wild plants in Barbados. This dipterous pest usually attacks a high percentage of the leaves of cucurbits. The numbers of mines per leaf vary at different times of the year and also according to the age of the plants. Heavily infested leaves are completely covered by mines, resulting in leaf death. The levels of infestation recorded between 1978 and 1984 are given in Table 2.

Table 2. Average percentage leaf infestation and average number of mines per leaf of *Liriomyza sativae*, for the years 1978 and 1984.

Year	Average per cent leaf infestation	Average number of mines/leaf
Sept. 1978 to Dec. 1980	70	8
1981	71	14
1982	80	8
1983	73	3
1984	78	8

On cucurbits, the pest is usually parasitised by a number of indigenous and exotic parasites, such as *Chrysocharis* spp., *Cirrospilus* sp., *Diaulinopsis* sp., *Diglyphus* sp. and *Opius* sp. The combined levels of parasitism between 1978 and 1984 are given in Table 3.

Table 3. Combined percentage parasitism by five parasites on leaf miners, recorded between 1978 and 1984, in Barbados.

Year	Percentage parasitism	
	Range	Average
1978–80	24–50	37
1981	26–39	20
1982	0–11	4
1983	2–69	21
1984	2–40	19

Besides *Opius* sp., *Chrysocharis* sp. and *Diglyphus* sp. were also introduced from Pakistan, but, because of their incomplete determinations (generic identifications only) it is difficult to say if these parasites became established in Barbados.

Other Crops and Pests

Other important pests, against which a large number of exotic, natural enemies have been introduced and have established in Barbados (and later released in the Leeward and Windward islands) include the following:

Armyworms

Spodoptera spp. (*Spodoptera frugiperda* (J.E. Smith)), *Spodoptera eridania* (Cramer), *Spodoptera latifascia* (Wlk.) and *Spodoptera sunia* (Guenee) are common and attack many crops.

S. frugiperda, the fall armyworm, is the most serious pest of maize and the damage is particularly serious on the young crop. The pest also attacks vegetables, cotton, sweet potato and white and prickly *Amaranthus* spp. (Alam, 1978). Although some 13 parasite species, and a large number of predators, attack the eggs, larvae and pupae in the field (Alam, 1978), it continues to cause serious crop losses. In efforts to reduce these losses, a large number of parasites have been obtained from India and Pakistan (Alam, 1974). Some of these were liberated directly in the fields, while others were mass multiplied in the laboratory and regular releases made over a period of time. As a result of these efforts, some parasites have established permanently, while others were recovered for only a short period of time and then disappeared. The most important establishments were of the egg-parasites, *Telenomus remus* Nixon, *Trichogramma chilotraeae* Nagaraja and Nagarkatti, from India; of the larval parasites, *Apanteles marginiventris* (Cresson) from Pakistan; and of the pupal parasites, *Trichospilus diatraeae* C. and M., from India. Two larval parasites, *Campoletis flavicincta* (Ashmead) from Uruguay and *Campoletis chlorideae* Uchida from India and Pakistan were recovered after realeases, but later disappeared. Of those that established, *T. remus* has played a significant role in the control of *Spodoptera* spp. Over the years, the average, annual parasitism by *T. remus* has exceeded 70%, and as a result the pest population on maize has been significantly reduced. The parasite also attacks the egg-masses of other *Spodoptera* spp. on a wide range of cultivated and wild plants and keeps these species under excellent control.

During the early 1970 s, when onion *(Allium cepa)* was a newly introduced crop in Barbados, plants at the nursery stage were often attacked by another armyworm, *Spodoptera sunia* (Guenee). Repeated applications of chemical pesticides could not prevent serious defoliation, and time and again the crop had to be replanted. As *T. remus* was newly established in maize fields, a few releases were made in onion fields, where almost 100% of egg-masses became parasitised and the problem was solved. Since then, onions have remained free from this pest. Similarly, *S. sunia* was also a problem in cotton fields, but *T. remus* has subsequently controlled the pest efficiently.

Spodoptera eridania (Cramer) and *Spodoptera latifascia* (Wlk.) are the other species which are heavily parasitised in sweet potato, beets, cucurbits and other crops. The parasitism levels average above 75% throughout the year.

Amaranthus spp. are serious weeds in some of the vegetable fields in Barbados, and harbour very large populations of *Spodoptera* eggs. However, these eggs are heavily attacked by *T. remus* and *Trichogramma exiguum* Pinto and Platner *(=T. fasciatum = T. minutum)* and serve as a parasite reservoir for the neighbouring vegetable fields where *Spodoptera* spp. lay their eggs.

In St. Kitts, *Spodoptera ornithogalli* (Guenee) and *Spodoptera latifascia* (Wlk.) were serious pests of peanuts *(Arachis hypogoea). T. remus* was successfully introduced from Barbados during 1980–81, and now attacks over 50% of egg-masses in the fields. As a result, pest populations have been reduced considerably. Since then, routine pesticide applications have been stopped by the National Agricultural Corporation (NACO), resulting in great savings to the farmers.

Cotton Semi-looper *(Pseudoplusia includens* (Walk.)*)*

This is an important pest of tomato, sweet potato, okra, beans and cucumbers, causing serious defoliation. Since the introduction and establishment of the polyembryonic, egg-larval parasite, *Copidosoma (=Litomastix)* sp. *(truncatellum* group*)* from India, the pest populations have been reduced significantly. Average levels of parasitism recorded on these crops were 79% on tomato, 79% on sweet potato, 33% on okra, 58% on beans and 25% on cucumbers (Alam, 1978).

The Yam Scale *(Aspidiella hartii* (Ckll.)*)*

Yam Scale infests yam tubers in the field and increases significantly in storage. Heavily infested tubers become unsightly, affecting their marketability. A local parasite, *Adelencyrtus moderatus* (Howard) *(=A. femoralis* Compere and Annecke), attacks a part of the scale population. The same parasite (possibly a different strain) was also introduced into Barbados from Trinidad. After realeases, the parasite became very abundant, so much so that some farmers reported an outbreak of some unknown pest in their storerooms. Parasitism levels on yam scales was over 95%. Since then, yams have remained relatively free of the pest.

Citrus Blackfly *(Aleurocanthus woglumi* Ashby*)*

Citrus Blackfly was first reported as a serious pest of citrus in Barbados by F.J. Simmonds in 1962. Bennett (1966) reported the successful introduction and establishment of two parasites – *Prospaltella opulenta* Silv. from Mexico and *Eretmocerus serius* Silv. from Jamaica in 1964. The establishment of these parasites saved the small citrus industry in Barbados (Alam, 1974).

The Onion Thrips *(Thrips tabaci* Lind.*)*

This is a serious pest, particularly during the dry season, on onions in Barbados and the Eastern Caribbean islands. Attempts to obtain the parasite, *Thripoctenus* sp., from India have been unsuccessful, but a fungus, *Entomophthora parvispora* MacLeod and Carl, was obtained from Europe. Infection occurred in the laboratory and infected larvae and adults were released in infested onion fields. No recoveries were made in subsequent surveys (Alam, 1974).

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