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# 3

## Biological Control in Barbados

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## Abstract

Early classical biocontrol successes in Barbados, some in combination with natural control, were the control of: sugarcane borers, sugarcane mealybugs and West Indian cane fly in sugarcane; cottony cushion scale and citrus blackfly in citrus; coconut whitefly in palm; fall armyworm in vegetables and field crops; diamondback moth in cruciferous crops; and green scale and whitefly on fruit and ornamental trees. Recent successes concern classical biocontrol, often in combination with natural control, of: the pink hibiscus mealybug in various crops and ornamentals; sago palm scale on cycads and ornamental palm; and the citrus leaf miner and the Asian citrus psyllid in citrus. Natural control included that of: papaya mealybug in papaya; chilli thrips in various crops; and red palm mite in coconut palm, ornamentals and bananas. Parasitoids were most often used, followed by predators, while microbial agents were rarely used. Barbados has regularly served as provider of natural enemies for other islands in the Caribbean. The island has faced at least 25 arthropod invasions of pests since 2000, stressing the need for biocontrol solutions.

## 3.1 Introduction

Barbados has an estimated population of slightly more than 290,000 (July 2017) and its main agricultural products are sugarcane, vegetables and cotton (CIA, 2017).

## 3.2 History of Biological Control in Barbados

The text of this section is a summary of information presented in Cock (1985).

### 3.2.1 Period 1830–1969

Many classical and a few augmentative and conservation biocontrol activities took place in Barbados during this period. They are summarized for the main crops below and in [Table 3.1](#).

#### *Biological control of pests in sugarcane*

Sugarcane was the most important crop in this period and biocontrol was attempted against major pests of this crop with a number of major successes.

**HARD-BACK BEETLES.** The larvae of hard-back beetles *Phyllophaga* spp., *Clemora smithi* Arr., commonly known as white grubs, feed on roots of sugarcane and other crops. *Bufo marinus* L., the giant toad, was introduced from Guyana in about 1830. It was said to have reduced pest populations, but due to lack of breeding sites for the toad, its population went down. During the

1910s releases of the major parasitoid of *C. smithi*, *Tiphia parallela* Smith, were made but without clear success. New attempts to control the pest were proposed in the 1920s consisting of releases of *T. parallela* as well as planting of boraginaceous shrubs (*Cordia curassavica* (Jacq.) Roem. and Schult.) that provide food for the parasitoids, provision of breeding sites for *B. marinus* and introduction of other parasitoids. In the 1930s, new natural enemies were imported (the parasitoid tephritids *Myzinum ephippium* (F.) (= *M. xanthonotus* (Rohw.)), *M. haemorrhoidalis* F., and the scoliids *Campsomeris tricincta* F. and *C. trifasciata* (F.)) from Puerto Rico, but none became established. The predator *Ignelater luminosus* (Illiger), also introduced in this period from Puerto Rico, established well but did not control *C. smithi*.

**SUGARCANE MOTH BORERS.** Sugarcane moth borers, *Diatraea* spp., form the most important pests of sugarcane in the Caribbean region. In Barbados, only *Diatraea saccharalis* (Fabricius) is important; on other islands three other *Diatraea* species may cause problems as well. During the intensive programme against sugarcane stem borers the Centre for Agriculture and Biosciences International (CABI, at that time Commonwealth Institute of Biological Control (CIBC)) ran a substation in Barbados. From 1919 to 1959, inundative releases of *Trichogramma* spp. (supposedly *T. fuentesi* Torres and *T. exiguum* Pinto and Platner) were used for control of the borer. Early observations in the 1910s and 1920s showed that natural parasitism by *T. exiguum* and *Telenomus alecto* Crawford was too low for borer control. In 1929 mass rearing and inundative releases of *Trichogramma* commenced with strains obtained from the USA, Mexico, Antigua, St Lucia and Montserrat. Rearing took

**Table 3.1.** Overview of major biocontrol activities in Barbados.

Biocontrol agent / exotic (ex), native (na)	Pest / crop	Type of biocontrol <sup>a</sup> / since	Effect / established or not / area (ha) under biocontrol <sup>b</sup>
<b>PERIOD 1830–1999<sup>c</sup></b>			
<i>Bufo marinus</i> / ex	Hard-back beetles (white grubs) sugarcane	CBC / 1830	Some control, not established
<i>Tiphia parallela</i> / na		CBC / 1910–20	Not established
<i>Myzinum ephippium</i> / ex		CBC / 1930	Not established
<i>M. haemorrhoidalis</i> / ex		CBC / 1930	Not established
<i>Campsomeris tricincta</i> / ex		CBC / 1930	Not established
<i>C. trifasciata</i> , / ex		CBC / 1930	Not established
<i>Ignelater luminosus</i> / ex		CBC / 1930	No control, established
<i>Trichogramma</i> spp. / na	Sugarcane moth borers, sugarcane	NC / 1919–59	Poor control
<i>Telenomus alecto</i> / na		NC / 1919–59	Poor control
<i>Trichogramma</i> spp. / ex		ABC / 1930–59	Poor control
<i>Ipobracon grenadensis</i> / ex		CBC / 1920s	Poor control, temp established
<i>I. puberuloides</i> / ex		CBC / 1920s	Not established
<i>Agathis stigmatera</i> / ex		CBC / 1920s	Poor control, established
<i>Agathis</i> sp. / ex		CBC / 1920s	Not established
<i>Lixophaga diatraeae</i> / ex		CBC / 1930–60	No control, established
<i>Paratheresia claripalpis</i> / ex		CBC/ 1934–1960s	No control, not established
<i>Cotesia flavipes</i> / ex		CBC / 1966	Good control, established / 1,733 ha
<i>Lixophaga diatraeae</i> / ex		CBC / since 1930	Good control, established / 1,733 ha
<i>Tetrastichus haitiensis</i> / ex	Sugarcane root borer, sugarcane	CBC / 1931 + 1973	No control, not established
<i>Hololepta quadridentate</i> / ex		CBC / 1950–51	No control, not established
<i>Fidiobia citri</i> / ex		CBC / 1974 + 1976	?, ?
<i>Brachyufens osborni</i> / ex		CBC/ 1976	No control, not established
<i>Plagioprospherysa trinitatis</i> / na	Jumping borer, sugarcane	NC / 1960s	Poor control
<i>Macrocentrus</i> sp. / ex		CBC / 1973	No control, not established
<i>Cryptolaemus montrouzieri</i> / ex	Mealybugs, sugarcane, various other crops	CBC / 1968–69	Partial control, established
<i>Hyperaspis</i> sp. / ex		CBC / 1968–69	No control, ?
<i>Nephus</i> sp. / ex		CBC / 1968–69	No control, ?
<i>Anagyrus saccharicola</i> / ex		CBC / 1970	Control, established / 1,733 ha
<i>Herpestes auropunctatus</i> / ex	Rats, sugarcane	CBC / 1872	Bad side effects, established
<i>Rodolia cardinalis</i> / ex	Cottony cushion scale, citrus	CBC / 1943	Good control, established / part of 243 ha
<i>Anicetus</i> sp. / ex		CBC / 1961	?, ?
<i>Brethesiella abnormicornis</i> / ex		CBC / 1961	?, ?

Continued

**Table 3.1.** Continued.

Biocontrol agent / exotic (ex), native (na)	Pest / crop	Type of biocontrol <sup>a</sup> / since	Effect / established or not / area (ha) under biocontrol <sup>b</sup>
<i>Eretmocerus serius</i> / ex	Citrus blackfly, citrus	CBC / 1965–65	Good control, established / part of 243 ha
<i>Encarsia opulenta</i> / ex		CBC / 1965–65	Good control, established / part of 243 ha
<i>Pseudozaya trinitatis</i> / ex	Coconut scale, coconut palm	CBC / 1940s	? / established
<i>Cryptognatha nodiceps</i> / ex		CBC / 1940s	? / ?
<i>C. simillima</i> / ex		CBC / 1940s	? / ?
<i>Penttilia insidiosa</i> / ex		CBC / 1940s	? / ?
<i>Zagloba aenipennis</i> / ex		CBC / 1940s	? / ?
<i>Encarsiella noyesi</i> / ex	Coconut whitefly, coconut palm	CBC / 1950–51	Good control, established / 550 ha
<i>Nephaspis amnicola</i> / ex		CBC / 1951	? / established
<i>N. nigra</i> / ex		CBC / 1951	? / established
<i>Trichogramma fasciatum</i> / na	Pink bollworm, cotton	ABC / 1930	Control, area unknown
<i>Bracon greeni</i> / ex		CBC / 1970s	?, ?
<i>Bracon gelechiaae</i> / ex		CBC / 1970s	?, ?
<i>Apanteles angeleti</i> / ex		CBC / 1970s	?, ?
<i>Rogas aligarhensis</i> / ex		CBC / 1970s	?, ?
<i>Compsilura concinnata</i> / ex	Armyworms, vegetables and field crops	CBC / 1931–32	No control, not established
<i>Archytas marmoratus</i> / ex		CBC / 1952	?, established
<i>Telenomus remus</i> / ex		CBC / 1968	Control, established / part of 600 ha
<i>Blaesoxipha filipjevi</i> / ex	Locusts, vegetables and field crops	CBC / 1970s	No control, not established
<i>Scelio aegyptiacus</i> / ex		CBC / 1970s	No control, not established
<i>Scelio</i> sp. nr. <i>serdangensis</i> / ex		CBC / 1970s	No control, not established
<i>Entomophthora parvispora</i> / ex	Thrips, vegetables and field crops	ABC / 1973–76	No control, not established
Native natural enemies	Agromyzid leaf miners, vegetables	NC	Partial control
<i>Diglyphis minoews</i> / ex		CBC / 1972–75	No control, not established
<i>D. sp. ?isaea</i> / ex		CBC / 1972–75	No control, not established
<i>Chrysocharis</i> sp. / ex		CBC / 1972–75	No control, not established
<i>Opius</i> sp. / ex		CBC / 1972–75	No control, not established
<i>Synopeas</i> sp. / ex	Tomato flower midge, vegetables	CBC / 1974–75	No control, not established
<i>Cotesia glomeratus</i> / ex	Cabbage butterfly, cruciferous crops	CBC / 1970 & 1981	No control, not established
<i>Diadegma pierisae</i> / ex		CBC / 1970 & 1981	No control, not established
<i>Pteromalus puparum</i> / ex		CBC / 1970 & 1981	No control, established
<i>Compsilura concinnata</i> / ex		CBC / 1981	No control, not established
<i>Trichogramma</i> sp. / na	Loopers, cotton and cruciferous crops etc	NC	Control on cotton, not on cabbage

Continued

Table 3.1. Continued.

Biocontrol agent / exotic (ex), native (na)	Pest / crop	Type of biocontrol <sup>a</sup> / since	Effect / established or not / area (ha) under biocontrol <sup>b</sup>
<i>Cotesia</i> sp. / na		NC	Control on cotton, not on cabbage
<i>Apanteles</i> sp. / na		NC	Control on cotton, not on cabbage
<i>Euplectrus platyhypenae</i> / na		NC	Control on cotton, not on cabbage
<i>Litomastix</i> sp. / na		NC	Control on cotton, not on cabbage
<i>Brachymeria</i> sp. / na		NC	Control on cotton, not on cabbage
<i>Winthemia</i> sp. / na		NC	Control on cotton, not on cabbage
<i>W.</i> sp. ? <i>pyrrhopyga</i> / na		NC	Control on cotton, not on cabbage
<i>Litomastix</i> sp. <i>truncatella</i> / ex	Loopers, vegetables	CBC / 1975	Partial control, established, part of 600 ha
<i>Trichospilus pupivora</i> / ex		CBC / 1982	?, established
<i>Apanteles</i> sp. / na	Diamondback moth	NC	Insufficient control
<i>Trichogramma</i> sp. / na		NC	Insufficient control
<i>Spilochalcis hirtifemora</i> / na		NC	Insufficient control
<i>Cotestia plutellae</i> / ex		CBC / 1968–1976	Partial control, established / part of 600 ha
<i>Tetrastichus sokolowskii</i> / ex		CBC / 1968–1976	Good control, established / part of 600 ha
<i>Diadromus collaris</i> / ex		CBC / 1968–1976	?, established
<i>Macromalon orientale</i> / ex		CBC / 1968–1976	?, not established
<i>P. xylostella</i> polyhedrosis virus / ex		CBC / 1968–1976	?, ?
<i>Goniozus</i> sp. <i>punctulaticeps</i> / ex	Pigeon pea pod borers, field crops	CBC / 1952–1974	No control, not established
<i>Apanteles etiellae</i> / ex		CBC / 1952–1974	No control, not established
<i>Bracon cajani</i> / ex		CBC / 1952–1974	No control, not established
<i>B. thurberiphagae</i> / ex		CBC / 1952–1974	No control, not established
<i>Phanerotoma bennetti</i> / ex		CBC / 1952–1974	No control, not established
<i>Eiphosoma dentator</i> / ex		CBC / 1952–1974	No control, not established
<i>Agathis</i> sp / na	Sweet potato leaf roller, field crops	NC	Insufficient control
<i>Nemorilla</i> sp. / na		NC	Insufficient control
<i>Eiphosoma dentator</i> / ex		CBC / 1974	No control, established
<i>Phanerotoma</i> sp. / ex		CBC / 1974	No control, not established
<i>Trichogrammatoidea bactrae</i> / ex		CBC / 1975	No control, not established
<i>Ardalus scutellatus</i> / ex	Arrow root leaf roller, field crops	CBC / 1982	No control, not established
<i>Dinarmus vagabundus</i> / ex	Legume seed weevils, field crops	CBC / 1974–75	?, ?
<i>D. basalis</i> / ex			
<i>Cephalosporium lecanii</i> / na	Scales, fruit and ornamental trees	NC / 1910	Control / part of 243 ha
<i>Pachylister chinensis</i> / ex	House and stable flies	CBC / 1950	No control, not established
<i>Muscidifurax</i> spp. / ex		ABC / 1969–70	?, ?

Continued

**Table 3.1.** Continued.

Biocontrol agent / exotic (ex), native (na)	Pest / crop	Type of biocontrol <sup>a</sup> / since	Effect / established or not / area (ha) under biocontrol <sup>b</sup>
<i>Spalangia nigra</i> / ex		ABC / 1969–70	?, ?
<i>Sphegigaster</i> sp. / ex		ABC / 1969–70	?, ?
<i>Pachycrepoideus vindemiae</i> / ex		ABC / 1969–70	?, ?
<i>Melanagromyza cuscatae</i> / ex	Love vine weeds	CBC / 1967–68	No control, not established
<i>Smicronyx roridus</i> / ex		CBC / 1967–68	No control, not established
<i>Athesapeuta cyperi</i> / ex	Nutgrass weed, vegetables and field crops	CBC / 1974–76	No control, not established
<i>Bactra</i> spp. / ex		CBC / 1974–76	No control, not established
<b>PERIOD 2000–NOW<sup>d</sup></b>			
<b>Predators</b>			
<i>Allograpta exotica</i>	Aphids, various crops	NC	Control, ?
<i>Amblyseius</i> sp.	Red palm mite, various palms	CBC	Control, established
<i>Chrysoperla</i> sp.	Lepidopterans, aphids, mites, thrips etc., various	NC	Control, ?
<i>Chrysoperla externa</i>	Chilli thrips, other thrips, red palm mite, various	NC	Control, ?
<i>Cryptolaemus montrouzieri</i>	Mealybugs, lepidopterans, thrips, aphids, various	NC	Control, ?
<i>Cryptolaemus montrouzieri</i>	Pink hibiscus mealybug, various plants	NC	Control, large areas
<i>Cycloneda sanguinea</i>	Lepidopterans, aphids, mites, thrips, various	NC	Control, ?
<i>Cryptolaemus montrouzieri</i>	Papaya mealybug, papaya	NC	Control, ?
<i>Cycloneda sanguinea</i>		NC	Control, ?
<i>Lestodiplosis</i> sp.		NC	Control, ?
<i>Cybocephalus nipponicus</i>	Sago palm scale, ornamental palms	CBC	Control, established, ?
<i>Franklinothrips vespiformis</i>	Chilli thrips and other thrips, various crops	NC	Control, ?
<i>Haplothrips gowdeyi</i>	Thrips, vars crops	NC	?, ?
<i>Orius insidiosus</i>	Chilli thrips and other thrips, mites, various	NC	Control, ?
<i>Telsimia</i> sp.	Red palm mite, various palms	NC	Control, ?
<b>Parasitoids</b>			
<i>Acerophagus papaya</i>	Papaya mealybug, papaya	NC	Control, ?

Continued

**Table 3.1.** Continued.

Biocontrol agent / exotic (ex), native (na)	Pest / crop	Type of biocontrol <sup>a</sup> / since	Effect / established or not / area (ha) under biocontrol <sup>b</sup>
<i>Ageniaspis citricola</i>	Citrus leaf miner, citrus	CBC	Control, established / part of 243 ha
<i>Anagyrus loeckii</i>		NC	Control / part of 243 ha
<i>Anagyrus kamali</i>	Pink hibiscus mealybug, various plants	CBC	Control, established / large areas
<i>Coccobius fulvus</i>	Sago palm scale, ornamental palms	CBC	Control, established, ?
<i>Euplectrus</i> sp.	<i>Alabama argillacea</i> , cotton	NC	Control, ?
<i>Tamarixia radiata</i>	Asian citrus psyllid, citrus	CBC	Control, established / part of 243 ha
<i>Trichogramma chilonis</i>	<i>Helicoverpa</i> / <i>Heliothis</i> spp., various crops	NC	?, ?

<sup>a</sup>Type of biocontrol: ABC = augmentative, CBC = classical, ConsBC = conservation biological control, NC = natural control

<sup>b</sup>Area of crop harvested in 2016 according to FAO (2018)

<sup>c</sup>All information based on Cock (1985)

<sup>d</sup>All information based on Colmenarez *et al.* (2014, 2016); and Ian Gibbs and Yelitza Colmenarez, St. Thomas, Barbados, October 2018, personal communication

place on *Sitotroga cerealella* Oliver and cards with parasitized eggs were put into sugarcane fields. Millions of *Trichogramma* were released, but no evidence was found that they gave any control.

Next, during the 1920s, parasitoids (the braconids *Ipoobracon grenadensis* Ashmead, *I. puberuloides* Myers, *Agathis stigmatera* (Cresson) and *Agathis* sp.) were imported from Guyana, Argentina and Venezuela, and *C. curassavica* was planted to provide food for the parasitoids. *I. grenadensis* temporarily established and *A. stigmatera* was recovered in 1935.

Also the dipteran parasitoid *Lixophaga diatraeae* (Townsend) was released in large numbers on several occasions during the period 1930–1960, with populations obtained from Antigua, Cuba, Dominican Republic and Jamaica. Recoveries were made, but *L. diatraeae* did not control *D. saccharalis* on that occasion. Attempts to establish *Paratheresia claripalpis* Van der Wulp from 1934 to the mid-1960s failed.

Due to the poor success obtained with the above-mentioned natural enemy introductions, the Asian parasitoid *Cotesia flavipes* (Cameron) was imported from India in 1966. The species was recovered in 1967 and a mass rearing was

initiated for releases in 1968 and 1969, resulting in island-wide establishment. During this period, *L. diatraeae* became more abundant and the two parasitoids have produced continuous sugarcane borer control.

**SUGARCANE ROOT BORER.** Sugarcane root borer *Diaprepes abbreviatus* (L.) had no native parasitoids in Barbados. Therefore, the egg parasitoid *Tetrastichus haitiensis* Gahan was imported from Haiti and Puerto Rico in 1931 and was mass reared and released for several years, but without success. In 1950–1951, the beetle *Hololepta quadridentata* (Olivier) was shipped several times from Trinidad and Tobago and released, but did not recover. In 1973, *T. haitiensis* was introduced again, this time from Montserrat, but did not establish. In 1974 and 1976, the egg parasitoid *Fidiobia citri* (Nixon) was introduced from Jamaica. In 1976, the egg parasitoid *Brachyufens osborni* (Dozier) was imported from Florida, USA, but did not establish.

**SUGARCANE MEALYBUGS.** Of the two sugarcane mealybugs *Saccharicoccus sacchari* (Ckll.) and *Dysmicoccus boninsis* (Kuwana), generally found



wherever sugarcane is grown, only *S. sacchari* is causing temporary problems. Coccinellid predators (*Cryptolaemus montrouzieri* Mulsant, *Hyperaspis* sp. and *Nephus* sp.) were imported from India in 1968–1969 and released, but information about establishment is not available. In 1970 the parasitoid *Anagyrus saccharicola* Timb. was imported from East Africa, reared and released. It established, became widespread and is believed to have reduced mealybug populations.

**JUMPING BORER.** Jumping borer *Elasmopalpus lignosellus* Zell. became a problem with the introduction of pre-harvest burning at the end of the 1960s. The parasitoid *Plagioprospherysa trinitatis* Thomps. was imported from Trinidad and Tobago in 1973, but appeared to be already present in Barbados. Its effect on jumping borer populations is not known. In the same period, several shipments of *Macrocentrus* sp. were received from Trinidad and Tobago but it has not been recovered.

**WEST INDIAN CANE FLY.** The West Indian cane fly *Saccharosydne saccharivora* (Westw.) is under natural control in Barbados.

**RATS.** The small Indian mongoose *Herpestes auro-punctatus* (Hodgson) was introduced to Barbados from Jamaica somewhere after 1872 for control of rats. With the exception of Jamaica, import and releases of the mongoose on many of the Caribbean island is now considered a serious mistake. Insectivorous lizards (*Ameiva* spp.) have become rare or extinct; also, mongooses are pests of poultry.

#### *Biological control of pests in citrus*

**COTTONY CUSHION SCALE.** Cottony cushion scale *Icerya purchasi* Maskell was found on the island in 1938 and developed to pest status by 1941. Not only citrus, but also pigeon pea, casuarina and other garden plants were attacked. Through CIBC (now CABI), *Rodolia cardinalis* (Mulsant) was introduced in 1943, which established and successfully controlled the scale. Surveys in the 1960s showed that the pest was still under good biological control by *R. cardinalis*. In 1961 the encyrtid parasitoids *Anicetus* sp. and *Brethesiella abnormicornis* (Gir.) were sent from Trinidad and Tobago to Barbados, but results of the introduction are unknown.

**CITRUS BLACKFLY.** Citrus blackfly *Aleurocanthus woglumi* Ashby was first found on the island in 1964. Apparently the citrus blackfly had already been present a few years, because dead and weakened trees were found where blackfly was present. *Eretmocerus serius* Silvestri was obtained in 1964 from Jamaica and *Encarsia opulenta* (Silvestri) in 1964–1965 from Mexico. The parasitoids were released, established, spread rapidly and successfully controlled the pest within a year. Later studies showed that *E. opulenta* had replaced *E. serius*. Complete biocontrol of blackfly with the parasitoids prevented expensive chemical control.

#### *Biological control of pests in coconut palm*

**COCONUT SCALE.** After outbreaks of coconut scale *Aspidiotus destructor* Sign. at the end of the 1940s, coccinellid predators, including *Pseudozya trinitatis* (Marshall), *Cryptognatha nodiceps* Marshall, *C. simillima* Sic, *Pentilia insidiosa* Mulsant and *Zagloba aenipennis* (Sicard), were introduced from Trinidad and Tobago. In 1954 *P. trinitatis*, *Prodilis* sp. and *Scymnus* sp. were found in Barbados.

**COCONUT WHITEFLY.** Coconut whitefly *Aleurodicus cocois* (Curt.) is a pest of coconut and ornamental plants in Barbados. Large numbers of the parasitoid *Encarsiella noyesi* Hayat were introduced from Trinidad in 1950 and 1951; the parasitoid rapidly established and provided excellent control of the whitefly. Also several scymnine coccinellids, including *Nephaspis amnicola* Wingo and *N. nigra* Gordon, were introduced in 1950 from Trinidad and these coccinellids were reported to have established in 1951.

#### *Biological control of pink bollworm in cotton*

Pink bollworm *Pectinophora gossypiella* (Saund.), native to India, was found in Barbados in 1920 and developed into a major pest. In the 1930s, the pest became less of a problem, which was thought to be the result of mass releases of *Trichogramma fasciatum* (Perkins) (= *minutum* Auct.) made against *D. saccharalis* (F.) in sugarcane, because this egg parasitoid also attacks *P. gossypiella*.

### *Biological control of armyworms on vegetables and field crops*

The following species of armyworms occur in the region: *Spodoptera frugiperda* (J.E. Smith), *S. latifascia* (Wlk.), *S. dolichos* (F.), *S. eridania* (Cram.), *S. exigua* (Hb.), *S. sumia* (Gn.), *Helicoverpa zea* (Boddie) and *H. virescens* (F.). *Compsilura concinnata* (Meigen), a European tachinid which has a wide host range, was introduced from Massachusetts into Barbados in 1931–1932 to control lepidopterous pests of crops including sweet potato, maize, cotton and cover crops, but did not establish. In 1952, tachinids, including *Archytas marmoratus* Tns, have been imported from Trinidad and Tobago; *A. marmoratus* was found in Barbados in surveys from 1969 onwards. Since 1968, a large number of natural enemies have been imported into Barbados from Pakistan and Trinidad. Of these, *Telenomus remus* Nixon became established and rates of parasitism of more than 80% were observed on several crops; the parasitoid substantially reduced *Spodoptera* populations.

### *Biological control of green scale and whitefly on fruit and ornamental trees*

Green scale *Coccus viridis* (Green) is a pest of several fruit and ornamental trees. In 1910, the fungus *Cephalosporium* (= *Lecanicillium*) *lecanii* Zimm. was found attacking *Saissetia nigra* (Nietn.) on hibiscus. Branches with fungus-infested scales were attached to mango, cherry and ornamental trees with *C. viridis*, *C. mangiferae* (Green), *Pulvinaria pyriformis* (Ckll.), *Vinsonia stellifera* (Westw.) and other scales. *Coccus* spp. and *P. pyriformis* were being killed by the fungus and became rare. Another fungus that resembled the 'cinnamon fungus in Florida' was found on *C. viridis* on coffee. Spores of this fungus were then sprayed on *C. viridis* and a whitefly on *Ipomea* sp. and seemed to control both effectively.

### *Biological control of house and stable flies*

Attempts to control houseflies (*Musca* spp.) and stable flies (*Stomoxys* spp.) started in 1950 by importing the predator *Pachylister chinensis* Quensel from Trinidad and Tobago, but it was not recovered after release. In 1969–1970 many individuals of *Muscidifurax* spp., *Spalangia nigra*

Latreille and *Sphegigaster* sp., originating from California and reared in Trinidad, were released in Barbados, as well as the Trinidad species *Pachycrepoideus vindemiae* Rond. Results of the releases are not available.

### *Biological control of love vine weeds*

The semi-parasitic love vines *Cuscuta americana* L. and *C. indecora* Choisy were kept under good control by legally enforced measures for many years, but once vigilance was relaxed the vines spread rapidly. In 1967–1968 an agromyzid *Melanagromyza cuscutae* Hering and a seed-feeding weevil *Smicronyx roridus* Mshl. were imported from Pakistan, reared and released, but did not establish. In 1971, *Smicronyx rufovittatus* Anderson was imported from Pakistan, but there is no information whether it established.

### *Barbados as provider of natural enemies*

During the period up to 1969, Barbados provided several natural enemies to other islands in the region. The giant toad *B. marinus* was moved to most of the Caribbean islands, as well as to Bermuda, after 1830. *Rodolia cardinalis* was sent on several occasions to other islands after its establishment in Barbados in the 1940s. *Cotesia flavipes* and *Lixophaga diatraeae*, which had been shown to reduce sugarcane borers effectively in the 1960s in Barbados, have been exported to other islands in the region and established. Barbados provided the parasitoid *A. saccharicola*, a natural enemy of sugarcane mealybugs, to islands in the region in the 1970s, where it also became established. *Telenomus remus*, an effective parasitoid of *Spodoptera* species in Barbados since 1968, has been sent to other islands.

## **3.2.2 Period 1970–2000**

### *Biological control of pests in sugarcane*

*Cotesia flavipes*, imported and released at the end of the 1960s (see above), and the native *L. diatraeae* have resulted in continuous control of sugarcane borer *D. saccharalis*. In 1970 the parasitoid *A. saccharicola* was imported from East Africa; it was reared and released, established and became widespread and is believed to have

reduced *S. sacchari* mealybug populations. The West Indian cane fly *S. saccharivora* is under natural control in Barbados.

#### *Biological control of pests in citrus*

Since the introduction of parasitoids in 1964 (see above), citrus blackfly has been under effective control by *E. opulenta* in Barbados. Cottony cushion scale *I. purckasi* has been under effective classical biocontrol in Barbados since the introduction of *R. cardinalis* in 1943 (see above) (Cock, 1985).

#### *Biological control of coconut whitefly*

The coconut whitefly *A. cocois* has been under effective biocontrol in Barbados since the import and release of *E. noyesi* in 1951 (see above) (Cock, 1985).

#### *Biological control of pink bollworm in cotton*

In 1974, 1975 and 1976 four species of parasitoids (*Bracon greeni* Ashmead, *Bracon gelechia* Ashmead, *Apanteles angeleti* Mues., *Rogas aligarhensis* (Quadri)) and the predator *Coranus spiniscutus* Reuter were introduced from Asia to Barbados. However, it seems they did not become established as no recoveries have been made since their release in the field. Ingram (1980) reported the parasitoid *Perisierola nigrifemur* Ashmead attacking *P. gossypiella* in Barbados. This parasitoid is very common in pink bollworm larvae towards the end of the season, but this timing is considered to be too late to be of economic value. Another biocontrol agent reported attacking diapausing larvae of the pink bollworm was the predatory mite *Pyemotes ventricosus* (Newport). This is very common at the end of the cotton crop and during the close season. Ingram (1980) supposed that this predatory mite exerts considerable control of long-cycle larvae at the field level.

#### *Biological control of pests in vegetables and other field crops*

ARMYWORMS. Since 1968, large numbers of natural enemies have been imported into Barbados from Pakistan and from Trinidad and Tobago. Of these, *T. remus* became established and sub-

stantially reduced *Spodoptera* populations on several crops

LOCUSTS AND GRASSHOPPERS. *Schistocerca pal-lens* (Thnb.) attacks crops as well as grasslands. In the early 1970s attempts to establish *Blaesox-iphia filipjevi* Rhod. from East Africa and the sceli-onids *Scelio aegyptiacus* Priesne and *Scelio* sp. nr. *serdangensis* (Timb.) from Pakistan failed.

THRIPS. *Thrips tabaci* Lind. is a serious pest in Barbados. The fungus *Entomophthora parvispora* MacLeod & Carl was imported from Switzerland on several occasions during 1973–1976 and infested thrips were released in the field, but not recovered.

TOMATO FLOWER MIDGE. Larvae of the tomato flower midge *Contarinia lycopersici* Felt cause wilting, flower shed and distorted fruit in tomato. The parasitoid *Synopeas* sp. was imported from Trinidad and Tobago in 1974–1975 and released but did not establish.

AGROMYZID LEAF MINERS. Agromyzid leaf miners *Liriomyza sativae* (Blanch.) and *L. trifolii* (Burgess) are pests of various vegetables. Native natural enemies do reduce leaf-miner populations, but for better control the parasitoids *Diglyphus minoetus* (Wlk.) and a *Diglyphus* sp. similar to *D. isaea* (Wlk.), along with *Chrysocharis* sp. and *Opius* sp., were imported from Pakistan from 1972 to 1975 and released, but no recoveries were reported.

PIGEON PEAS POD BORERS. The pigeon peas pod borers *Fundella pellucens* Zell. (= *cistipennis* Dyar) and to a lesser extent *Ancylostoma stercorea* (Zell.) cause problems in Barbados. Parasitoids of *A. stercorea* (*Goniozus* sp. *punctulaticeps* group, *Apanteles etiellae* Vier., *Bracon cajani* Mues., *B. thurberiphagae* (Mues.), *Phanerotoma bennetti* Mues. and *Eiphosoma dentator* (E.)) were introduced from Trinidad between 1952 and 1974, but no recoveries were reported from pigeon peas.

SWEET POTATO LEAF ROLLER. Sweet potato leaf roller *Syllepte helcitalis* (Wlk.) is a minor pest in Barbados. The native parasitoids *Agathis* sp. and *Nemorilla* sp. cause only 5% parasitism. The parasitoids *E. dentator* (from Trinidad and Tobago) and *Phanerotoma* sp. (1974) and *Trichogrammatoidea bactrae* Nagaraja (1975), both from India, were

introduced. Only *E. dentator* was recovered, but parasitism of the leaf roller was very low.

**ARROWROOT LEAF ROLLER.** Arrowroot leaf roller *Calpodex ethlius* (Stoll) is the principal pest of arrowroot (*Maranta arundinacea* L.). The parasitoid *Ardalus scutellatus* (How.) was introduced from St Vincent in 1982, but no results of the introduction were reported.

**LEGUME SEED WEEVILS.** Legume seed weevils *Callosobruchus chinensis* (L.) and *C. maculatus* (F.) attack black-eye peas and the parasitoids *Dinarmus vagabundus* (Timb.) and *D. basalis* (Rond.) were introduced from India in 1974 and 1975 to control these pests. No results of these releases have been published.

#### *Biological control of pests on fruit and ornamental trees*

**GREEN SCALES.** Green scale and several other scale species that are pests of fruit and ornamental trees have been controlled by a native fungus, *C. lecanii*, since the 1910s (see above). In 1972, the parasitoid *Adelencyrtus moderatus* (How.), or *A. odonaspidis* Fullaway, of the yam scale *Aspidiella hartii* (Ckll.) was imported from Trinidad for control trials on various scale species, though the parasitoid was known to be present already. Results of the trials are not known.

**ORTHEZIA SCALES.** *Orthezia insignis* Browne and/or *O. praelonga* (Dgl.) cause problems in citrus, coffee, croton and other ornamentals. In 1976 and 1977, coccinellid predators (*Hyperaspis distinguenda* (Muls.), *H. donzeli* (Muls.) and *H. jucunda* (Muls.)) were imported from Trinidad, but no recoveries have been reported.

#### *Biological control of pests of cruciferous crops*

**CABBAGE BUTTERFLY.** The cabbage butterfly *Ascia monuste* (L.) causes problems on crucifers in Barbados. In 1970–1971, the parasitoids *Apanteles glomeratus* (L.), *Diadegma pierisae* (Rao) and *Pteromalus puparum* (L.) were imported from Pakistan, but did not establish. In 1981, the same three species together with the tachinid *C. concinnata* were imported from Pakistan and some pupae parasitized by *P. puparum* were recovered.

**CABBAGE LOOPERS.** The cabbage loopers *Trichoplusia ni* (Hb.) and *Pseudoplusia* (= *Chrysodeixis*) *inclusens* (Wlk.) feed on a wide range of host plants, including legumes, crucifers, cotton, okra and solanaceous crops. They are parasitized by a number of native natural enemies, including: *Trichogramma* sp.; *Apanteles* (*Cotesia*) sp. poss. *marginiventris* (Cress.); *Apanteles* (*Glyptapanteles*) sp.; *Euplectrus platyhyphenae* How.; *Litomastix* sp. nr. *truncatella* (Dalm.); *Brachymeria* sp.; *Winthemia* sp. nr. *pinguis* F.; and a *Winthemia* sp. similar to *W. pyrrohopyga* (Wied.). On cotton they are normally kept in check by their natural enemies, but on cabbage they are serious pests. *Litomastix* sp. *truncatella* group was imported from India in 1975, reared and released. The species established in many crops and levels of parasitism rose from 5% before the introduction to 25% (on cabbage) and 79% (on tomato) in 1982. In 1981, *Trichospilus pupivora* (= *pupivorus*) Ferriere, introduced to control *Spodoptera* spp., was found to attack *P. inclusens* in Barbados.

**DIAMONDBACK MOTH.** The diamondback moth *Plutella xylostella* (L.) became a problem in the Caribbean during the 1950s and 1960s. Native parasitoids (*Apanteles* sp., *Trichogramma* sp. and the hyperparasitic chalcidid *Spilochalcis hirtifemora* (Ashmead.)) attack the moth, but insufficiently to be able to control it. Between 1968 and 1976, the parasitoids *Cotesia* (*Apanteles*) *plutellae* (Kurdjumov), *Tetrastichus sokolowskii* Kurd., *Diadromus collaris* (Grav.) and *Macromalon orientale* Kerrich and a sample of a *P. xylostella* polyhedrosis virus were shipped to Barbados from India. Recoveries of *C. plutellae* and *D. collaris* were reported. Further releases of *C. plutellae*, reared in Trinidad and Tobago and in Barbados, were made between 1968 and 1973. Surveys showed that *C. plutellae* obtained up to 52% parasitism. Additional releases of *T. sokolowskii* reared from stocks obtained from Montserrat were made in 1973. *T. sokolowskii* established and resulted in levels of parasitism of 68–100% in 1976.

#### *Biological control of nutgrass weed*

Nutgrass *Cyperus rotundus* L., native to Pakistan and India, is now a worldwide pest and occurs in crops including sugarcane, cotton and vegetables

in the Caribbean. The weevil *Athesapeuta cyperi* Mshl. and two species of the tortricid genus *Bactra* were imported in 1974–1976 from Pakistan, but did not establish.

#### *Barbados as provider of natural enemies*

Barbados provided *C. pluteellae* during this period to several other islands in the region

### 3.3 Current Situation of Biological Control in Barbados

#### 3.3.1 Classical biological control of pink hibiscus mealybug

The pink hibiscus mealybug *Maconellicoccus hirsutus* (Green) was introduced into Barbados in 2000 and attacks different ornamentals and agricultural crops. It is a very prolific pest that causes severe distortion of leaves, new shoots and fruits. Initial use of chemical and cultural control was ineffective. Two natural enemies of the mealybug were tested for classical biocontrol: *C. montrouzieri*, which was sourced and released locally, and *Anagyryus kamali* Moursi, which was brought from Grenada and Trinidad and Tobago through CABI. Use of these natural enemies resulted in effective biocontrol of the pest (Ian Gibbs, St Thomas, Barbados, October 2018, personal communication).

#### 3.3.2 Natural biological control of the papaya mealybug

The papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink was introduced into Barbados in 2000. High population densities of the mealybug cause deformation of new growth, leaf yellowing, leaf curl and early fall of fruits. With the objective of establishing a biocontrol programme of this pest, the Ministry of Agriculture of Barbados and the State University Paulista (UNESP-FCA, Jaboticabal, Brazil) determined the complex of natural enemies of the pest in Barbados. The most efficient parasitoids found were *Acerophagus papaya* Noyes &

Schauff and *Anagyryus loeckii* Noyes & Menezes, and the most important predators were *Lestodiplosis* sp., *Cycloneda sanguinea* Linnaeus and *C. montrouzieri*. The pest was successfully controlled using these indigenous natural enemies. Currently the above-mentioned parasitoids and predators are commonly found attacking the pest in the field (Ian Gibbs and Yelitza Colmenarez, Botocatu, Brazil, October 2018, personal communication).

#### 3.3.3 Classical biological control of the sago palm scale

The sago palm scale *Aulacaspis yasumatsui* Takagi was introduced into Barbados in 2003, infesting cycads and other ornamental palms. Initial damage appears as chlorotic spots. Highly infested cycads are heavily coated with a white crust that includes scales of live and dead insects. Biocontrol had earlier been used successfully to manage the sago palm scale (Cave, 2006). The Ministry of Agriculture of Barbados collaborated with R. Cave from the University of Florida and imported the parasitoid *Coccobius fulvus* (Compere and Annecke) and the predatory beetle *Cybocephalus nipponicus* Endrödy-Younga. Both species were reared at the field level at different locations on the island, resulting in successful biocontrol. Currently, these natural enemies are collected from fields where biocontrol works well and are then released in new areas affected by the pest (Ian Gibbs, St Thomas, Barbados, October 2018, personal communication).

#### 3.3.4 Classical biological control of the citrus leaf miner

The citrus leaf miner *Phyllocnistis citrella* Stainton was introduced into Barbados in 2000. In collaboration with the University of Florida, *Ageniaspis citricola* Logvinovskaya was introduced, but the initial introduction did not result in sufficient control of the pest, as the citrus plantations were not pruned and the parasitoids had difficulty in finding the preferred early larval stages. When parasitoids were released after pruning, excellent biocontrol was obtained.

An indigenous parasitoid, a species of the genus *Cirrospilus*, was reported to attack the citrus leaf miner (Ian Gibbs and Yelitza Colmenarez, Botocatu, Brazil, October 2018, personal communication).

### 3.3.5 Classical biological control of Asian citrus psyllid

The Asian citrus psyllid *Diaphorina citri* Kuwayama, native to southern Asia, is a vector of the most serious citrus disease worldwide, the bacterium *Candidatus liberibacter*, commonly referred to as citrus greening or huanglongbing (HLB) (literally, yellow dragon disease). According to a report by FAO (2013), the psyllid is present in Barbados, as well as the disease causing *Candidatus liberibacter asiaticus*, but not *Candidatus liberibacter americanus*. The report mentioned a number of management methods, including biocontrol of the psyllid with the parasitoid *Tamarixia radiata* (Waterston). Currently *T. radiata* is mass reared at field level in collaboration with the University of Florida and CABI. This methodology allowed the establishment of the Asian citrus psyllid/HLB biocontrol programme, despite the limited laboratory infrastructure on the island. Parasitoid mass rearing and releases strongly reduced psyllid populations and avoided the presence of the HLB disease on the island for many years (Ian Gibbs, St Thomas, Barbados, October 2018, personal communication)

### 3.3.6 Natural biological control of the chilli thrips

The chilli thrips *Scirtothrips dorsalis* Hood was introduced into Barbados in 2005 and attacks different crops. It has a great reproductive potential together with the ability to adapt easily to new areas. In Barbados, different predators attack the chilli thrips, e.g. *Franklinothrips vespiformis* Crawford, *Orius insidiosus* (Say) and *Chrysoperla externa* (Hagen) (Ian Gibbs, St Thomas, Barbados, and Yelitza Colmenarez, Botocatu, Brazil, October 2018, personal communications).

### 3.3.7 Natural biological control of the red palm mite

The red palm mite *Raoiella indica* Hirst was introduced into Barbados in 2010. This prolific invasive species attacks different hosts, including *Cocos nucifera* (L.), ornamentals and *Musa* sp. Colmenarez *et al.* (2014) studied the population trends of this species on different Caribbean islands and found entomopathogenic fungi, of which three isolates of the genus *Simplicillium* are most interesting as they might have potential for biocontrol of the red palm mite in the Caribbean. In Barbados the pest was also found to be attacked by a predatory mite belonging to the genus *Amblyseius* and by other predators, e.g. the coccinellid *Telsimia* sp. and neuropteran *C. externa* (Ian Gibbs, St. Thomas, Barbados, October 2018, personal communication).

### 3.3.8 Natural enemies of cotton pests

Colmenarez *et al.* (2016) studied natural enemies of pests of 'West Indian Sea Island Cotton' (*Gossypium barbadense* L.) by weekly monitoring of the crop during two production seasons (2009–2011). Seven species of predators and two parasitoids were found. However, cotton farmers frequently apply chemical control and often confuse natural enemies with pests, treating them with pesticides. Training of farmers and development of IPM programmes using biocontrol were suggested by Colmenarez *et al.* (2016) to prevent indiscriminate use of pesticides and increase the use of biocontrol agents in the island.

### 3.3.9 Areas under biological control in Barbados

Based on data about areas of agricultural products harvested in 2016 (FAO, 2018) and the successful cases of biocontrol listed in Table 3.1, the area under biocontrol in Barbados is estimated to be at least 3,000 ha, with about 300 ha under natural control, 2,700 ha under classical biocontrol and less than 10 ha under augmentative biocontrol.

**Table 3.2.** Overview of key pests introduced and established in Barbados (source: M. James, Barbados National Plant Protection Officer, October 2018, personal communication).

Common name	Scientific name	Year of introduction
Pink hibiscus mealybug	<i>Maconellicoccus hirsutus</i>	2000
Papaya mealybug	<i>Paracoccus marginatus</i>	2000
Citrus leaf miner	<i>Phyllocnistis citrella</i>	2000
Giant African snail	<i>Achatina fulica</i>	2000
Tomato russet mite	<i>Aculops lycopersici</i>	2000
Broad mite	<i>Polyphagotarsonemus latus</i>	2000
Gliricidia moth	<i>Azeta melanea</i>	2000
West Indian fruit fly	<i>Anastrepha obliqua</i>	2001
Pickle worm	<i>Diaphania nitidalis</i>	2002
Asian citrus psyllid	<i>Diaphorina citri</i>	2003
Varroa mite	<i>Varroa destructor</i>	2003
Sago palm scale	<i>Aulacaspis yasumatsui</i>	2003
Chilli thrips	<i>Scirtothrips dorsalis</i>	2005
Soybean scale	<i>Crypticeria genistae</i>	2006
Cotton stainer	<i>Dysdercus discolor</i>	2006
Dendrobium/hibiscus midge	<i>Contarinia maculipennis</i>	2006
Ficus thrips	<i>Gynaikothrips uzeli</i>	2006
Fig whitefly	<i>Singhiella simplex</i>	2007
Red palm mite	<i>Raoiella indica</i>	2010
Cardin's whitefly	<i>Metaleurodicus cardini</i>	2011
Croton scale	<i>Phalacrocooccus howertoni</i>	2011
Erythrina gall wasp	<i>Quadrastichus erythrinae</i>	2012
Duges wax scale	<i>Ceroplastes dugesii</i>	2014
Crepe myrtle aphid	<i>Sarucallis kahawaluokalani</i>	2015
Avocado lace bug	<i>Pseudacysta perseae</i>	2015

### 3.4 New Developments of Biological Control in Barbados

The constant movement of people and intense international trade that Barbados experiences result in introduction and establishment of new pests and invasive species in the country. Recent invasions are summarized in Table 3.2. Several biocontrol programmes have recently been successfully developed as a sustainable approach to face those challenges and these have been summarized above. Other programmes are still in development, like biocontrol of chilli thrips, red palm mite and pests in cotton.

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