

OVERVIEW OF BIOLOGICAL CONTROL OF LEPIDOPTERA IN THE CARIBBEAN

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ABSTRACT

Some previous biological control programs in the Caribbean are listed. Three cases are considered in detail: 1) Biocontrol of the sugarcane borer (*Diatraea saccharalis*) has been a notable success, with effective control in several countries in the Caribbean. The braconid parasitoid *Cotesia flavipes* has been shown to be particularly adaptable to new hosts and future studies should exploit this quality still further. 2) Biocontrol of the diamondback moth on the other hand has been generally less successful, mostly due to the very low economic threshold required of crucifers but also because the parasitoids that have been tried up to now do not seem to work as well in the hot tropics as in more temperate areas. 3) Biocontrol of the pigeonpea pod borer is still in its infancy but is a suitable case for treatment.

The past history of lepidopteran biocontrol in the Caribbean suggests that prolonged effort over many years yields results. It is difficult to finance years of sustained effort; the challenge for the future is to coordinate the endeavors of several Caribbean organizations in order to focus them on a few key pest problems.

RESUMEN

Se mencionan algunos programas de control biologico en el Caribe. Tres casos se consideran en detalle. 1) El exito notable del control biologico del barrenador de la caña de azucar *Diatraea saccharalis* en la region del Caribe. Se ha demostrado que el parasitoide braconido *Cotesia flavipes* se puede adaptar a nuevos hospederos, y estudios futuros deben explotar esta cualidad. 2) El control biologico de la polilla diamante ha tenido menos exito, debido a el bajo nivel de daño economico que se requiere en las cruciferas, y tambien porque los parasitoides que han sido probados hasta ahora, no parecen ser efectivos tanto en el tropico caliente como en las areas templadas. 3) El control biologico del barrenador del gandul esta en vias de desarrollo pero puede mejorarse.

The purpose of this paper is to review some features of lepidopteran biological control in the region and to draw some inferences about where trends may be leading. It is not intended to be comprehensive and it will be biased towards those areas where IIBC (formerly CIBC) has expertise or interests.

Past attempts in the English speaking Caribbean were reviewed by Cock (1985) to which the reader is referred for more detail. He mentions around 50 Caribbean pest genera, of which 16 are Lepidoptera. A list of non-crucifer lepidopteran biocontrol attempts appears in Table 1 (for more on crucifer biocontrol, see Alam 1992).

Instead of reviewing past attempts we will deal with three cases in more detail which cover a past success, a present initiative and a future challenge.

TABLE 1. BIOCONTROL OF SOME LEPIDOPTERAN SPECIES IN THE ENGLISH-SPEAKING CARIBBEAN (AFTER COCK 1985).

Palm Castnid (<i>Lapaeumides dedalus</i>)	Successful control claimed in Guyana by manipulation of a bacterium
Pink Bollworm (<i>Pectinophora gossypiella</i>)	Small parasitoid releases, no establishment
Cotton Leafworm (<i>Alabama argillacea</i>)	Small predator releases, no establishment
Giant Moth-Borer (<i>Castnia licoides</i>)	Small parasitoid releases, no establishment
Jumping Borer (<i>Elasmopalpus lignosellus</i>)	Small parasitoid releases, no establishment
Sugarcane borers successes (<i>Diatraea saccharalis</i>)	Many parasitoid releases, establishment of several species, notable successes
Tomato pinworm (<i>Keiferia lycopersicella</i>)	Small parasitoid releases, no establishment
Pigeonpea Borer (<i>Fundella pellucens</i>)	Small to moderate releases, no establishment
Sweet Potato Leafroller (<i>Syllepte helcitalis</i>)	Small parasitoid releases, no establishment
Arrowroot Leafroller (<i>Calpodus ethlius</i>)	Small parasitoid releases, one species established
Armyworms (<i>Spodoptera</i> & <i>Heliothis</i>) 20 species shipped to Barbados (1968-1976), numerous releases, two established, <i>Telenomus remus</i> claimed as a success. 18 species released in Trinidad (1973-1982), none established.	

BIOCONTROL OF SUGARCANE BORERS (*DIATRAEA* SPP.)

Biocontrol of *Diatraea saccharalis* (F.) is the most outstanding success story of biocontrol in the Caribbean and in some ways it is an unlikely one. *Diatraea* spp. are indigenous, having adapted to the Polynesian sugarcane from local wild grasses. Some native parasitoids followed them to the introduced plant, but others did not, probably because of the greater protection to *D. saccharalis* afforded by the thick stemmed cane.

Attempts at biocontrol have been going on for over 60 years, and at least 54 species of parasitoids (12 tachinids, 42 hymenopterans) have been studied as possible candidates for release.

Trichogramma spp. egg parasitoids were first released massively in 1921 in Guyana. Bates (1954) carried out mass release experiments with controls for five successive years but could find no differences between release and control plots. Later Metcalfe & Breniere (1969) concluded that this was not effective for sugarcane; nevertheless *T. minutum*, *T. fasciatum*, *Telenomus alecto* and *Trichogrammatoidea eldanae* were still being released in Guyana in 1990 against *D. centrella* - apparently without effect (Quashie-Williams, pers. comm.).

Tachinid and braconid parasitoids have been more successful however, and a summary of successful establishments appears in Table 2. There have also been similar successes in S. America, the most recent in Venezuela where the release of *Cotesia flavipes* reduced damage to well below the economic threshold.

These successes have been mostly against *D. saccharalis*, and in many cases it is now *D. centrella* which is the main pest because of its ability to encapsulate the parasitoid's eggs within the hemocoel. There is anecdotal evidence however that *C.*

TABLE 2. SUMMARY OF SUCCESSFUL ESTABLISHMENTS OF PARASITIDS OF *DIATRAEA* SPP. (AFTER COCK 1985).

Country Results	Species established
Antigua Moderately successful Sugar production now stopped	<i>Lixophaga diatraeae</i>
Barbados Together give good control	<i>Lixophaga diatraeae</i> <i>Apanteles flavipes</i>
Dominica Good control; <i>P. claripalpis</i> more important	<i>Lixophaga diatraeae</i> <i>Paratheresia claripalpis</i>
Guyana Good control of <i>D. saccharalis</i>	<i>Metagonistylum minenese</i>
Jamaica Moderate control	<i>Apanteles flavipes</i>
St Kitts Effective until 1960 Moderate control	<i>Lixophaga diatraeae</i> <i>Apanteles flavipes</i>
St Lucia Good control	<i>Metagonistylum minenese</i>
Trinidad Fairly good control	<i>Apanteles flavipes</i>

flavipes has overcome this problem in some areas. Other parasitoids such as *Allorhogas pyralophagus* and *Pediobius furvus*, are being tried in Guyana.

The success of *C. flavipes* against *D. saccharalis* is particularly noteworthy. *Diatraea* spp. was not its original host. *C. flavipes* is a native of the oriental region, between 32° N and 22° S in S.E. Asia (Mohyuddin 1971) where it has been reported from a large number of pyralid and noctuid graminaceous stem borers. Mohyuddin et al. (1981) studied the strain of *C. flavipes* established in Pakistan on the maize borer *Chilo partellus*. By analyzing behavior and host preference, they found that this strain is adapted to maize and sorghum borers and is not attracted to even its preferred host, *C. partellus*, when fed on sugarcane. The attraction is elicited by kairomones present in the mandibular glands as well as frass of the host larvae.

Mohyuddin introduced sugarcane-adapted strains of *C. flavipes* from Indonesia and elsewhere. Laboratory tests confirmed its preference for sugarcane, it was released and quickly became established on the sugarcane borers *Chilo infuscatellus* and *Acigona steniellus*. The various strains were crossed in the laboratory and interbred freely, producing viable off-spring, confirming that they are the same species.

Such host plant preferences can be changed by laboratory selection. Parasitoid females having preference for *C. partellus* in maize were reared on the sugarcane borer *C. infuscatellus* in sugarcane. The females showing preference for sugarcane were selected, in an olfactometer, over successive generations and were used to produce the next generation. With the first generation, 6% of females showed preference for sugarcane, 52% for maize and the rest showed no preference. Selection for sugarcane produced a 45% preference for sugar after 4 generations. Strains of *C. flavipes* from different regions in Asia apparently have different responses to both stemborer hosts and host plants of various pyralids and noctuids; a current IIBC-ICIPE program for *C. partellus* in E. Africa will take this research further.

In the Caribbean, where *C. flavipes* switched to *Diatraea saccharalis*, there may well have been natural selection of both its host finding mechanism and its ability to avoid encapsulation. It seems likely that such host switching is more common than previously realized and there remains the tantalizing potential to modify the host preference and specificity of *C. flavipes* still further, to develop strains more effective against *D. centrella* and other species. To do this however, we need a considerable research effort and some insight into why *C. flavipes* is sometimes not so successful (e.g. in Jamaica).

BIOCONTROL OF THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* (L.)

This pest of truly global significance probably originated from the Mediterranean region. It attacks crucifers which are generally temperate crops, and where cultivation has spread to the tropics the moth has followed. One of the main problems to overcome in controlling this pest is the very low economic threshold, which can be less than 1 larva per plant. This has meant heavy use of insecticides which has provoked severe resistance problems. *Bacillus thuringiensis* (BT) can be effective against the pest, but resistance is appearing to this as well (e.g. in Hawaiian watercress cultivation (Biocontrol News & Information 1991)).

There have been some successes with the use of parasitoids. IIBC achieved almost total control of the pest in the Cape Verde Islands with *Cotesia plutellae*. The introduction of *Diadegma semiclausum* into highland Brassica crops in Malaysia, Taiwan and Indonesia has given excellent results, displacing *C. plutellae* and usually eliminating the need for pesticides. Attainment of this control has been greatly slowed by continuing pesticide use, and only the adoption of BT has permitted biocontrol to develop to its full potential—in the Malaysian Cameron Highlands this took 12 years. Generally though, in the hot humid tropics classical biocontrol of the moth has had limited success. Both *D. semiclausum* and *C. plutellae* are not very effective under such extreme conditions and the prevailing opinion is that future biocontrol of the moth will have to be set firmly within a program for its integrated pest management. Pesticides, chemical or biological, will be required to complement any improved use of indigenous or introduced parasitoids.

Because of the effect of pesticides on *Plutella* biocontrol, IIBC surveyed global pesticide tolerance in *C. plutellae* and chose the most tolerant strain (from Malaysia) for introduction into Honduras, where it is now believed to be established at low densities (R. Cave, pers. comm.). Some pesticide tolerance has also been found in the Caribbean, but this can not be called proper resistance. A recent attempt to create fenitrothion-resistant *C. plutellae* at IIBC, achieved only a 2-3 fold increase in tolerance after 12 generations of selection from a field strain from a heavily sprayed region (Ke, Waage & Moore, unpublished data).

The use of parasitoids in the genera *Cotesia*, *Diadegma* and *Tetrastichus* is receiving renewed attention. A new Global Working Group on *Plutella* has been established in the IOBC, and its priority will be to resolve the confused taxonomic status of these parasitoids. Recent work by IIBC and the Escuela Agrícola Panamericana in Honduras, for example, has shown that *D. semiclausum* and the New World *D. insulare* will mate but produce nearly all male progeny, underlining the need for careful study of parasitoids before introduction.

With the support of the IOBC, IIBC and the Asian Vegetable Research and Development Centre are promoting a new exploratory program to seek strains and species from the hot lowland regions of the pest's region of origin, to obtain strains more tolerant of extreme tropical conditions. Thus although *P. xylostella* parasitoids are established on a number of Caribbean islands, due largely to the indefatigable efforts

of Munir Alam of CARDI, much work remains to be done on realizing their full potential through their integration with pesticide use and other control methods. Given the likelihood of rapid development of resistance to IGRs and BT if used indiscriminately, this research is urgent. There is also a need to look at new biological pesticides. IIBC, with the assistance of CARDI has recently isolated three fungal agents from *P. xylostella* in the Caribbean. IIBC will soon begin to investigate their use in formulations especially designed for application to vegetables under hot dry conditions, using technology developed in IIBC's biopesticide program for the desert locust.

THE PIGEONPEA POD BORER, *ANCYLOSTOMIA STERCOREA* (ZELL.)

This borer is the most serious pest of pigeonpea in most Caribbean Islands; the percentage of damaged peas frequently passes 50%. Pod life tables from cohorts of marked buds show that major mortality occurs to potential pods during the flowering stage, due probably to a physiological process. Nevertheless, appreciable mortality occurs during the pod stage as well, though it is difficult to isolate the causes of this mortality and the role that the borer plays in it, or conversely the role that pod drop might play in borer mortality.

Bennett (1960) details six parasitoids attacking *A. stercorea* in Trinidad. Five are larval, the sixth is egg-larval. Insecticides are not very effective because of the cryptic nature of the pest. IIBC has been carrying out some basic studies to understand more about the life history of the pest and its interactions with the parasitoid complex. Life table studies suggest that this complex is not controlling the borer very efficiently; for every hundred eggs laid, between 60 and 70 adults are produced. Mortality is relatively uniform through the larval stages and *Bracon thurberiphagae* appears to be the most important biotic factor.

The problem is similar to that of sugarcane, an indigenous borer on an introduced plant which has a natural enemy complex that is not controlling the pest. Innundation by *Trichogramma* is unlikely to be effective because some property of the eggs seems to deter attack. Chemical control is difficult, cultural control not effective. The obvious route to follow is to look for parasitoids on closely related species in other countries; the life table studies suggest there is plenty of room for another parasitoid to cause extra mortality during larval and pupal development. With the experience gained from strain selection of *C. flavipes*, we feel that future research on this problem is a worthwhile venture.

There are other control possibilities however where biocontrol should not be forgotten. This is in the area of plant breeding to produce resistant strains, or possibly strains that shed fewer flowers or varieties with an extended productive season. Let us look at these possibilities in turn.

Resistant strains might be developed to mechanically hinder entry of the young larva, or more likely, to augmenting deterrent chemicals or decrease moth attractants. This last mentioned factor is apparently the case for the differential attraction of *Helicoverpa armigera* attraction to cultivars of pigeonpea (Rembold & Tober 1985). It is very likely that the parasitoids are also attracted by plant substances themselves or plant chemicals that have been altered or released by the feeding of the moth larvae. (Turlings & Tumlinson 1991). In any resistant variety trials, it would be very important to make sure that such synomones were still manufactured by the plant so that the control by natural enemies would not decline on the introduction of a new variety.

If a strain could be produced to augment numbers of pods surviving to maturity, would this be of use or would the moth population merely increase in proportion? The available evidence suggests that moth population increase would be unlikely because of the density dependent mode of action of the natural enemies. From basic life-table data,

it should be possible to model the effect that increased pod production would have on pest numbers.

If a strain of pigeonpea had a longer flowering period, the effect that this would have on moth populations could also be modelled. Available evidence suggests that the parasitoids are building up too late in the season to have a marked effect on moth populations, so a prolonged season could be beneficial to parasitoid populations.

A possible scenario for future control of this pest might be: (a) Short term: use insecticides which have been screened for minimal effect on the parasitoid complex (already being undertaken). (b) Mid-term: look for foreign parasitoids, screen them in an olfactometer or wind-tunnel against borers on different varieties of the plant; if they are effective, release them and study them through life table analysis. (c) Long term: breed resistant varieties, including testing for attractiveness to parasitoids.

DISCUSSION

There have been many attempts to analyze biocontrol projects to discover basic principles governing success and failure. We do not propose to repeat these exercises, only to point to some areas we think are important.

From the history of biological control in the Caribbean (Table 1) it is clear that "small" is not beautiful. The greatest success, in sugarcane, has come from an outstanding effort over many years. Although there are many examples throughout the history of biocontrol where a few releases of a poorly studied parasitoid taken from one locality have been successful, the history of biocontrol of lepidopteran pests in the Caribbean belies this approach. It is no accident that most progress has been in the most important cash crop of the region. Even here however, the reasons for success are not readily apparent. Recent evidence (Pashley et al. 1990) suggesting that *D. saccharalis* may be two sibling species should surely give biocontrol workers cause for thought. Is this why *C. flavipes* has been so successful in some cases but not others? Or is it due to lability of the virus which the parasitoid female injects with her eggs to suppress the immune system? Biocontrol workers usually do not have the time or resources to consider these points and consequently the problem continues to be addressed by releases of various indistinguishable parasitoid "strains" with the hope that one will overcome the problem. The situation is analogous to insecticide companies which used to select chemicals by trial and error without trying to understand the physiology of the insect. They have changed their strategy; so should we.

The greatest challenge for small Caribbean islands is to make biocontrol work on small scale horticultural production. Fletcher et al. (1989) have shown that farmers in Trinidad get most of their advice from chemical companies. Extension services are limited and poorly financed on many islands and although pesticide regulations exist, there is often no means of enforcing them efficiently. In recent years CARDI has had notable successes with small farmer systems, though whether these can be sustained once support is removed has yet to be ascertained. With the many other socioeconomic problems afflicting such countries, pesticide abuse is viewed by some as a relatively minor problem and governments often lack the commitment to punish offenders. The only way that things are likely to change is if export commodities are refused entry to the US and elsewhere because of pesticide contamination. However in many cases vegetable production is mainly for local or regional consumption and there are no strong reasons why current practices should change markedly. Perhaps biopesticides will replace chemicals but it is likely that these too will be overused and induce resistance.

Future biocontrol ventures are likely to be most successful where there is strong export potential. With the decline of sugar and the concomitant diversification into other crops, there is a danger that research efforts will fragment into many small

projects that may deal with serious pest problems but will be too small to be able to pay for development of a sound biocontrol solution.

There is a need for a regional approach to rationalization of agricultural production so that long-term biocontrol and IPM solutions can be developed and implemented with sufficient funds. Rice in Guyana is an obvious candidate for biocontrol, fruit crops such as mango and citrus are another, drought-resistant crops such as pigeonpea could be a third. We should make strenuous efforts to coordinate the activities of the many research organizations in the region and to identify a few key pests on which to focus our attention; only in this way will we maximize chances of furthering the cause of biological control.

From the technical viewpoint, future projects should involve (1) extensive searches in countries of origin for natural enemies; (2) considerable effort to taxonomically characterize the material obtained and (3) after quarantine, a comprehensive breeding and testing phase which would involve olfactometers or a wind-tunnel to select and behaviorally classify candidate strains. Such work would be expensive but the increased level of success should make it cost effective.

At the very least, even if a project is not successful, we should be able to provide a scientifically argued reason for its failure so that we do not continue to repeat the mistakes of the past.

REFERENCES CITED

- ALAM, M. 1992. Use of parasitoids for the biological control of cabbage pests in the Caribbean. *Florida Ent.* 75: 493-505.
- BATES, J. F. 1954. The status of the moth borer in British Guyana. *Proc. British West Indies Sugarcane Technol.* 1954, 126-136.
- BENNETT, F. D. 1960. Parasites of *Ancylostomia stercorea* (Zell.), (Pyralidae, Lepidoptera) a pod borer attacking pigeon pea in Trinidad. *Bull. Ent. Res.* 50: 737-757.
- BIOCONTROL NEWS AND INFORMATION. 1991. Conference report. 12(1): 6.
- COCK, M. J. W. 1985. A review of biological control of pests in the Commonwealth Caribbean and Bermuda up to 1982. CIBC Tech. Comm. 9. CAB, UK.
- FLETCHER, L. M., R. H. SINGH, AND M. FARROE. 1989. The role of agricultural input suppliers in the transfer of agricultural technology in Trinidad and Tobago. 2nd Annual Seminar on Agricultural Research, Trinidad and Tobago November 1988.
- METCALFE, J. R., AND J. BRENIERE. 1969. Egg parasites (*Trichogramma* spp.) for control of sugar cane moth borers, pp. 80-115 in J. R. Williams, J. R. Metcalfe, R. W. Mungomery, and R. Mathes [eds.], *Pests of sugarcane*. Elsevier, Amsterdam, London, New York.
- MOHYUDDIN, A. I. 1971. Comparative biology and ecology of *Apanteles flavipes* (Cameron) and *Apanteles sesamiae* Cam. as parasites of graminaceous borers. *Bull. Ent. Res.* 61: 33-39.
- MOHYUDDIN, A. I., C. INAYATULLAH, AND E. G. KING. 1981. Host selection and strain occurrence in *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae) and its bearing on biological control of graminaceous stem-borers (Lepidoptera: Pyralidae) *Bull. Ent. Res.* 71: 575-581.
- PASHLEY, D. P., T. N. HARDY, A. M. HAMMOND, AND J. A. MIHM. 1990. Genetic evidence for sibling species within the sugarcane borer (Lepidoptera: Pyralidae). *Ann. Entomol. Soc. Am.* 83(6): 1048-1053.
- REMBOLD, H., AND H. TOBER. 1985. Kairomones as pigeonpea resistance factors against *Heliothis armigera*. *Insect Sci. Applic.* 6: 249-252.
- TURLINGS, T. C. J., AND J. H. TUMLINSON. 1991. Do parasitoids use herbivore-induced plant chemical defenses to locate hosts? *Florida Ent.* 74(1): 42-50.