BSES Limited

FINAL REPORT – SRDC PROJECT BSS249

PREPAREDNESS FOR BORER INCURSION

by

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SD03014

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EXECUTIVE SUMMARY

Moth borers are the most devastating pests of graminaceous plants, including sugarcane, in the world. Australia is so far free of all the major borer species, but several species occur in countries close to Australia, with some reaching as close as the Torres Strait islands. This project was carried out to increase Australia's preparedness for an incursion of an exotic cane borer.

The project started by developing Pest Incursion Management Plans (PIMPs) specific to each group of borers. PIMPs were developed for the borer genera *Chilo*, *Diatraea*, *Eldana*, *Sesamia* and *Scirpophaga*. The plans detail the steps to be taken in case of a borer incursion, and include extensive dossiers on each species with information on their distribution, host plants, symptoms, economic impact, morphology, detection methods, biology and ecology, natural enemies, management options and phytosanitary risk.

To speed up the identification process in the event of an exotic pest incursion, we constructed a molecular phylogeny tree that included 26 exotic species of borers belonging to 10 genera and 6 tribes. The rapid DNA-based identification methodology derived from this study, in cooperation with the Centre for Identification and Diagnostics, University of Queensland, has been transferred to BSES where it will be available for any future use. The method will reduce the time required to identify a borer species from weeks or months to days.

Pheromone traps were deployed in 10 sites across Queensland and the Torres Strait islands using delta traps and pheromone lures for 11 exotic species. No exotic species have been found. A list of native moths that were attracted to the lures was compiled; this is useful information as to what species are likely to respond to the same lures and be confused with target species in case of future pheromone deployment. The trapping technology has been transferred to the Northern Australian Quarantine Survey (NAQS) and NorthWatch for possible deployment on a regular basis.

A list of about 800 records of parasitoids, predators and pathogens of the 24 key moth borers in Asia and the Indian Ocean islands was compiled, with information on the host stage they attack, host plant or crop and country of record. This information will facilitate rapid decision-making regarding importation of a suitable natural enemy in case of a borer incursion. A significant outcome of this work was the development of a PhD project, through a link with Adelaide University, to look at the world (including Australian) population diversity of *Cotesia flavipes*. This species is a key parasitoid of stem borers, and strains suitable for borer control may already exist in Australia.

Following a search of literature, and discussions with entomologists in Papua New Guinea, South Africa and Louisiana, we identified two insecticides that could be used in Australia against an introduced borer. These are the moulting disruptor tebufenozide (Mimic®, Confirm® or RH-5992) and the pyrethroid lambda-cyhalothrin (Karate®). An emergency-use permit for off-label use in Australia could not be granted by the Australian Pesticides and Veterinary Medicines Authority (formerly NRA), as none of these pests are found in Australia. However, identification of these insecticides and the compilation of information to support their use against an incursion will minimize the time lost between detecting an exotic borer and use of the insecticide.

During 2003, BSES carried out a wide awareness campaign on procedures to follow if an incursion is suspected. This targeted a wide range of industry personnel, and the clear message to leave a suspected plant where it is and quickly report infestation to BSES was stressed. The campaign served as a prerequisite to a simulated incursion exercise that tested the industry's response to an incursion. Feedback was positive, especially with regards to the involvement of all Cane Productivity Services in regular routine surveys, and their willingness to be involved in emergency surveys if the need arises.

Finally, a simulation of incursion exercise was carried out to test our preparedness on both industry and national level. A phone conference, attended by the Chief Plant Protection Officer (AFFA), representatives of BSES, Plant Health Australia, QDPI, NorthWatch and Mossman Agricultural Services, was held. During the conference, we assumed that an exotic borer was detected in Mossman by BSES, who immediately informed BSES Head Office and triggered the appropriate chain of events. Based on the discussion that followed, we concluded that we are prepared to quickly respond to an incursion, and that an eradication campaign can be activated within a few days after detection. However, one particular issue needed to be followed up by BSES and QDPI; that is the formation of the Strategic Management Group that will convene in the area of incursion and be responsible for the delimiting surveys that will follow. The need arose to effectively define the members of that group and whether it is a BSES or a QDPI responsibility. It is envisaged that it is most likely to be a joint responsibility, since BSES will have the expertise in that particular area, and QDPI will have the legislative power to impose quarantine measurements and contribute to the delimiting surveys.

A major outcome of this project is the current wide awareness of the threat posed by exotic borers to Australia. Of equal importance, strong ties with various organizations were established which will serve as a solid base for further cooperation. A significant outcome of the project is the incorporation of PIMPs and other procedures in the Sugar Industry Biosecurity Plan being coordinated by Plant Health Australia (PHA). This initiative is strongly supported by federal and state government agencies and all sectors of industry through PHA members CANEGROWERS and BSES Limited. The dossiers also give much of the information necessary to categorise these pests under the cost-sharing agreement currently being brokered by PHA.

1.0 BACKGROUND

The Australian sugarcane industry has traditionally maintained a strict quarantine system concerning the movement of cane into Australia from other countries and between the cane growing regions within Australia. No plant material is allowed into the country without first going through these quarantine channels. Until recently, because the trade in sugarcane products was largely restricted to processed sugar and molasses rather than plant material, there was a negligible quarantine risk. During the 1990s, however, there was been an increased interest in the trade of used sugarcane machinery, use of sugarcane in traditional cooking, and the importation of germplasm for breeding purposes. These factors, combined with the increase in sugarcane production in Irian Jaya and Timor and the Ord River District, as well as increased movement of illegal entrants from Indonesia, have led to increased concerns about the accidental introduction of new sugarcane pests.

SRDC project BSS175 developed two important tools to reduce the impact of pest incursions. A Pest Risk Analysis identified 1286 species of insects and mites affecting sugarcane worldwide. Dossiers were prepared on each species and detailed taxonomic information, common names, synonyms, hosts, distribution, entry, colonisation, spread and establishment potentials, plant part affected and the physical damage and symptoms that may aid detection, general biology, pre- and post-incursion management options, the potential for economic damage to sugarcane, the estimated risk of incursion, quarantine assessment and the name of a contact person who could provide additional information. The project identified borers as the most significant incursion threat (FitzGibbon *et al.* 1999a,b). In the area to the immediate north of Australia, the borers *Sesamia grisescens*, *S. inferens*, *S. arfarki*, *Chilo auricilius*, *C. infuscatellus*, *C. sacchariphagus*, *C. partellus* and *Scirpophaga excerptalis* are important pests. Other species, including *Diatraea* and *Eldana*, are important borer pests in the Americas and Africa, respectively. The impact of any one of these pests on the Australian industry would be dramatic - yield losses of 33% of cane weight and 18% of sugar content are reported from overseas (FitzGibbon *et al.* 1999b).

The identification of these species is difficult, particularly if only larvae are collected and accurate identification is an urgent first step in dealing effectively with an incursion. Molecular methods, similar to those developed for canegrubs under BSS97, would provide accurate and rapid identification.

CSIRO Entomology (under an AQIS-funded project) has been developing pheromone-based traps for early detection of borer moths. Deployment of these traps across northern Australia (in conjunction with NAQS and NorthWatch programs) would provide an early warning system for incursions.

Insecticides and natural enemies are important tools for managing borer populations. Data exist in a variety of publications and Kuniata's PhD thesis (Kuniata 1999) that could be used to frame proactive applications for insecticide registrations and initiate the parasitoid-import process. It is important to first assess which of these natural enemies already exist in Australia.

A generalised Pest Incursion Management Plan was also prepared under BSS175 (Allsopp *et al.* 1999; FitzGibbon *et al.* 1999a). This details actions and responsibilities of governmental and industry organizations in the event of an incursion of an exotic pest. This has been distributed to all appropriate organizations. However, this generalised plan would be more useful if developed further to cover each of the important borer species in detail. The Australian industry needs to be made more aware of the actions detailed under these plans and the plans need to be tested under a simulated incursion.

A BRS-AFFA workshop on managing exotic pests held in 1999 identified the following key research areas: development of Pest Risk Analyses; development of incursion management plans for specific pests; implementation of monitoring and surveillance systems; identification of pathways for incursions; development of appropriate taxonomic and diagnostic methods; development of management responses, especially plant resistance, insecticides and biological controls.

This project aimed to improve Australia's preparedness for an incursion of an exotic borer of sugarcane.

2.0 OBJECTIVES

The project aimed to improve Australia's preparedness for an incursion of an exotic borer of sugarcane by:

- Developing pest-incursion management plans specific to each major exotic borer species;
- Developing accurate methods for the identification of larvae of exotic sugarcane borers;
- Implementing pheromone-based detection methods for exotic sugarcane borers;
- Paving the way for importation of important parasitoids of exotic sugarcane borers;
- Developing emergency-use permits for off label use of insecticides against exotic sugarcane borers;
- Developing a better awareness in the industry of the threats posed by exotic borers and of the appropriate responses and testing those responses.

All of the objectives of the project have been achieved to the extent possible.

Objective 1 – Development of pest-incursion management plans specific to each major exotic borer species.

Pest Incursion Management Plans (PIMPs) specific to the borers belonging to the genera *Chilo*, *Diatraea*, *Eldana*, *Sesamia* and *Scirpophaga* were developed and are available at www.bses.org.au. The plans detail the steps to be taken in case of a borer incursion, and include extensive dossiers on each species with information on their distribution, host plants, symptoms, economic impact, morphology, detection methods, biology and ecology, natural enemies, management options and phytosanitary risk.

These have received endorsement from a wide range of industry and government bodies – QDPI, NSW Agriculture, AgWest, AFFA, CANEGROWERS, ACFA, ASMC and Cane Productivity Services. All are currently available on the BSES Limited web site (www.bses.org.au) and hard copies have previously been sent to SRDC. Each has been incorporated into the Sugar Industry Biosecurity Plan currently under development by

Plant Health Australia (PHA), BSES and CANEGROWERS. The dossiers also give much of the information necessary to categorise these pests under the cost-sharing agreement currently being brokered by PHA.

Objective 2 – Development of accurate methods for the identification of larvae of exotic sugarcane borers.

DNA-based technology has been developed for the accurate identification of 26 exotic species of borers belonging to 10 genera and 6 tribes in a cooperative study with the Centre for Identification and Diagnostics, University of Queensland. This methodology has been transferred to BSES where it will be available for any future use. The method will reduce the time required to identify a borer species from weeks or months to days.

Objective 3 – Implementation of pheromone-based detection methods for exotic sugarcane borers.

Pheromone traps were deployed in 10 sites across Queensland and the Torres Strait islands using delta traps and pheromone lures for 11 exotic species. No exotic species were found. A list of native moths that were attracted to the lures was compiled; this is useful information as to what species are likely to respond to the same lures and be confused with target species in case of future pheromone deployment. The trapping technology has been transferred to the Northern Australian Quarantine Survey (NAQS) and NorthWatch (QDPI) for possible deployment on a regular basis.

Objective 4 - Paving the way for importation of important parasitoids of exotic sugarcane borers.

A list of about 800 records of parasitoids, predators and pathogens of the 24 key moth borers in Asia and the Indian Ocean islands was compiled, with information on the host stage they attack, host plant or crop and country of record. This information will facilitate rapid decision-making regarding importation of a suitable natural enemy in case of a borer incursion. A significant outcome of this work was the development of a PhD project, through a link with Adelaide University, to look at the world (including Australian) population diversity of *Cotesia flavipes*. This species is a key parasitoid of stem borers, and strains suitable for borer control may already exist in Australia.

Objective 5 – Development of emergency-use permits for off label use of insecticides against exotic sugarcane borers.

Following a search of literature, and discussions with entomologists in Papua New Guinea, South Africa and Louisiana, two insecticides that could be used in Australia against an introduced borer were identified. These are the ecdysone agonist tebufenozide (Mimic®, Confirm® or RH-5992) and the pyrethroid lambda-cyhalothrin (Karate®). An emergency-use permit for off-label use in Australia could not be granted by the Australian Pesticides and Veterinary Medicines Authority (formerly NRA), as none of these pests are found in Australia. However, identification of these insecticides and the compilation of information to support their use against an incursion will minimize the time lost between detecting an exotic borer and use of the insecticide.

Objective 6 - Development of better awareness in the industry of the threats posed by exotic borers and of the appropriate responses and testing those responses.

During 2003, BSES carried out a wide awareness campaign on procedures to follow if an incursion is suspected. This targeted a wide range of industry personnel, and the clear message to leave a suspected plant where it is and quickly report infestation to BSES was stressed. The campaign served as a prerequisite to a simulated incursion exercise that tested the industry's response to an incursion. Feedback was positive, especially with regards to the involvement of all Cane Productivity Services in regular routine surveys, and their willingness to be involved in emergency surveys if the need arises.

Finally, an exercise to simulate an incursion was carried out to test our preparedness at both industry and national level. A phone conference, attended by the Chief Plant Protection Officer (AFFA), representatives of BSES Limited, Plant Health Australia, QDPI, NorthWatch and Mossman Agricultural Services, was held. During the conference, we assumed that an exotic borer was detected in Mossman by a BSES entomologist, who immediately informed BSES Head Office and triggered the appropriate chain of events. Based on the discussion that followed, we concluded that we are prepared to quickly respond to an incursion, and that an eradication campaign can be activated within a few days after detection. However, one particular issue needed to be followed up by BSES and QDPI; that is the formation of the Strategic Management Group that will convene in the area of incursion and be responsible for the delimiting surveys that will follow. The need arose to effectively define the members of that group and whether it is a BSES or a QDPI responsibility. It is envisaged that it is most likely to be a joint responsibility, since BSES will have the expertise in that particular area, and QDPI will have the legislative power to impose quarantine measurements and contribute to the delimiting surveys.

A significant outcome of the project is the incorporation of PIMPs and other procedures in the Sugar Industry Biosecurity Plan being coordinated by Plant Health Australia (PHA). This initiative is strongly supported by federal and state government agencies and all sectors of industry through PHA members CANEGROWERS and BSES Limited.

3.0 INCURSION MANAGEMENT PLANS

During the 1990s, the Standing Committee on Agriculture and Resource Management (now Primary Industries Standing Committee – PISC) developed a general, non-specific, incursion-management strategy (SIMS) (Fig. 1) to manage responses to exotic pest incursions. This strategy, which largely remains current, outlines the broad areas of an incursion management plan and the appropriate authorities involved.

Figure 1 Sequence of steps, officers and organisations in the SCARM incursion management strategy (SIMS)

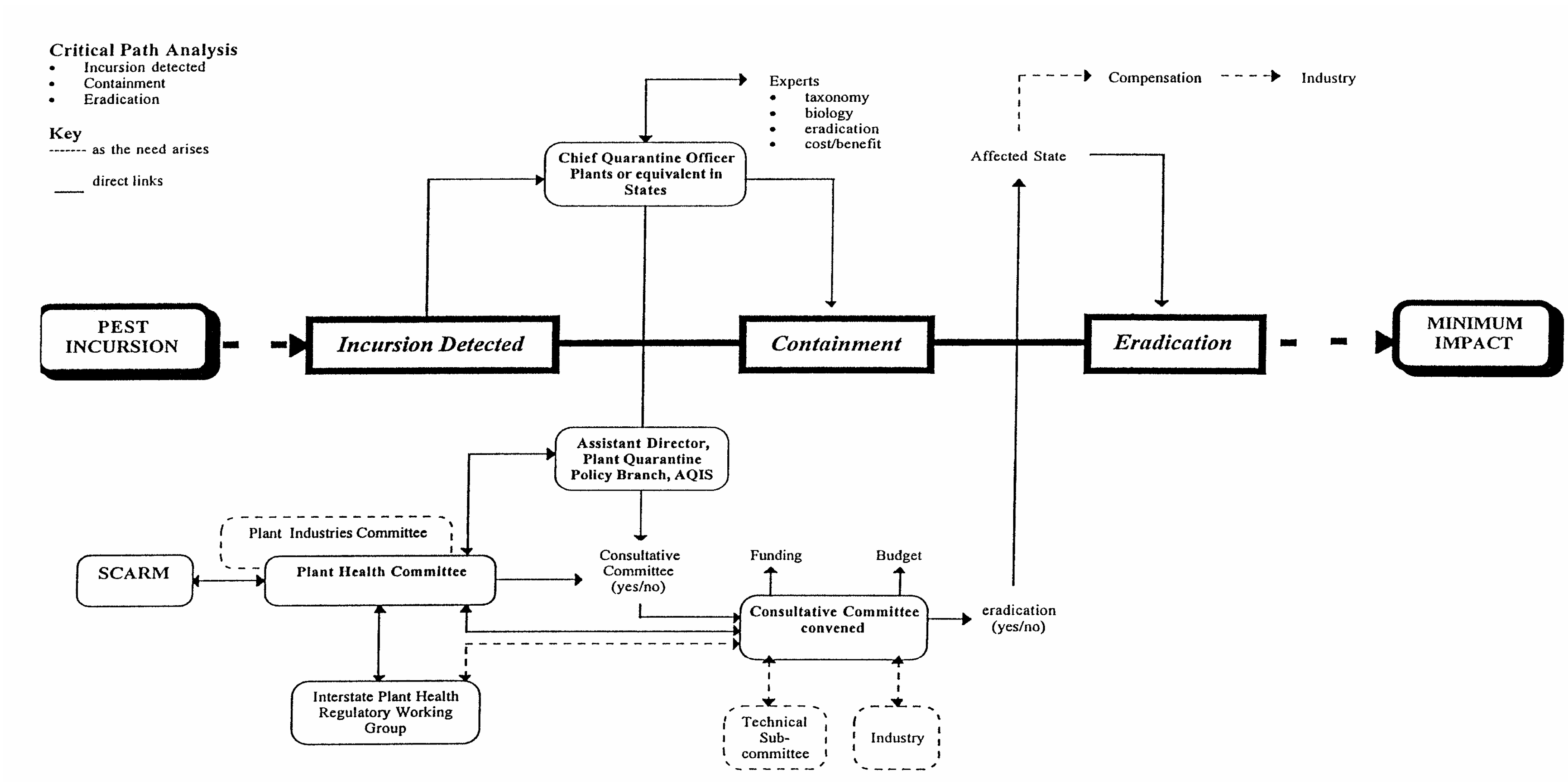
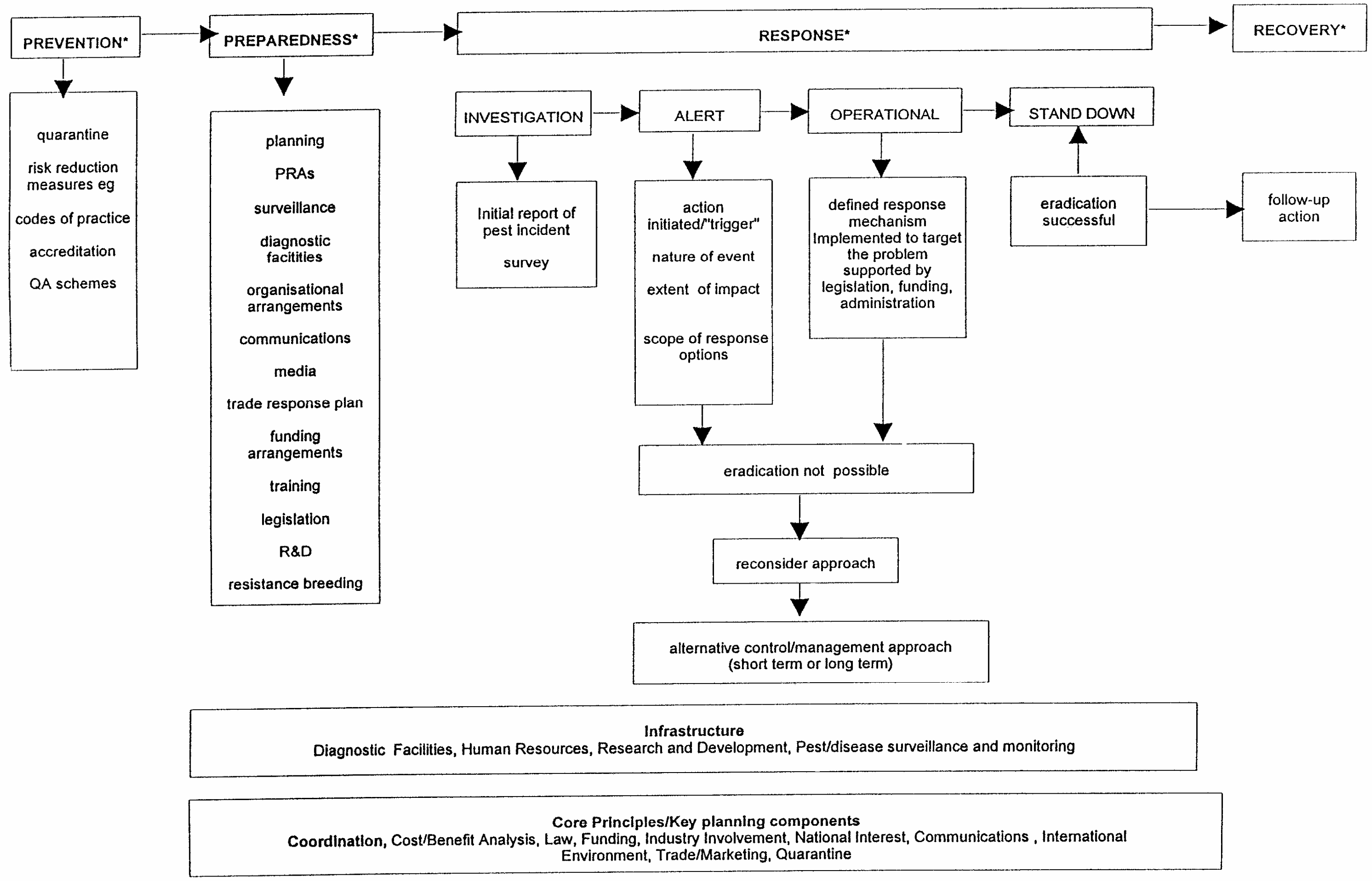


Figure 2 Generic incursion management plan (GIMP)



* Stages of the "all hazards" approach adopted by Emergency Management Australia

The key feature of the strategy is the operation of a national Consultative Committee on Exotic Plant Pests (CCEPP) that is convened under the auspices of Plant Health Committee after an incursion occurs. CCEPP is chaired by the Chief Plant Protection Officer (CPPO) in the Department of Agriculture, Fisheries and Forestry and its membership includes the State/Territory Chief Plant Biosecurity Officers. The CCEPP oversees the strategic management of the initial pest response and facilitates decisions on the feasibility of eradication and future direction of the response. It also makes recommendations on strategic response-management issues through Plant Health Committee and Primary Industries Health Committee to PISC, which comprises the chief executive officers of departments of agriculture/primary industries in the Commonwealth and States/Territories. The ultimate decision-making authority regarding pest responses is Primary Industries Ministerial Council, comprising the ministers of agriculture/primary industries in the Commonwealth and States/Territories.

The generic incursion management plan (GIMP) for the plant industries is a refinement of SIMS. This plan outlines the four steps to incursion management: prevention, preparedness, response and recovery (Fig. 2). These plans were used to develop a generic pest incursion management plan for sugarcane (Allsopp *et al.* 1999).

Here, we developed Pest-specific Incursion Management Plans (PIMPs) for the borer genera *Chilo*, *Diatraea*, *Eldana*, *Sesamia* and *Scirpophaga*. Each outlines appropriate responses, detail responsibilities, and provides a more expanded review of the biology, ecology and management of these species than that in the dossiers of FitzGibbon *et al.* (1998). A sample dossier is given in Appendix 1.

The PIMPs were developed by BSES and have received endorsement from a wide range of industry and government bodies – QDPI, NSW Agriculture, AgWest, AFFA, CANEGROWERS, ACFA, ASMC and Cane Productivity Services. All are currently available on the BSES Limited web site (www.bses.org.au) and hard copies have previously been sent to SRDC. Each has been incorporated into the Sugar Industry Biosecurity Plan currently under development by Plant Health Australia (PHA), BSES and CANEGROWERS. The dossiers also give much of the information necessary to categorise these pests under the cost-sharing agreement currently being brokered by PHA.

Brief notes are given below on each of the borer genera, including the 21 pest species that have potential to invade Australia and cause damage to sugarcane (Figures 3 and 4). Of that 21 species, we consider that seven would have medium to high potential of invading Australia and causing a high level of damage to sugarcane. These are species that are geographically close to Australia, and that have sugarcane as a main host. Detailed information on these pests is recorded in the PIMPs, including references to all statements below.

Figure 3 Damage to cane by *Chilo* sp. in Indonesia

Figure 4 Damage to cane from *Scirpophaga excerptalis* in Indonesia

3.1 Genus *Chilo*

The genus *Chilo* contains 41 species, and of these, 8 have potential of causing damage to Australian cane if they invaded the mainland: *Chilo agamemnon*, *C. auricilius*, *C. infuscatellus*, *C. orichalcociliellus*, *C. partellus*, *C. sacchariphagus*, *C. terrenellus* and *C. tumidicostalis*. Two other species may have negligible impact, if any, based on data on their biology and ecology in Africa: *C. diffusilineus* and *C. zacconius*. Additionally, two *Chilo* species are already in Australia: *C. polychrysus* and *C. suppressalis*. However, the exact identity of the species referred to as *C. polychrysus* in Australia needs to be confirmed, as it may be another closely related, unidentified species (ED Edwards, CSIRO Entomology, pers. comm.). *C. polychrysus* is a minor pest of rice, but is recorded as a minor pest of sugarcane in some countries in Asia (David & Easwaramoorthy 1990). However, *C. suppressalis* appears to be strictly a pest of rice, and we found no strong evidence in the literature that it could survive on sugarcane. The remaining 29 *Chilo* species are not known to be pests of sugarcane.

3.1.1 Borer *Chilo auricilius* Dudgeon

This species is a pest of sugarcane in South East Asia and a major cane pest in northern India. It is distributed through China, India, Sri Lanka, Burma, Hong Kong, Bangladesh, Nepal, Taiwan, Vietnam, Taiwan, Philippines, Thailand, and Indonesia (Moluccas, Celebes and Borneo). *C. auricilius* also feeds on rice and is considered to be one of its major pests in some parts of India and in Bangladesh. It is, however, regarded as a minor pest of rice in some parts of Papua New Guinea, where it does not seem to cause major damage to cane.

3.1.2 Borer *Chilo infuscatellus* Snellen

This is a major pest of sugarcane, but also attacks maize, millet, sorghum, rice, barley, oats, juar and many species of wild grasses. The pest is widely distributed in the former USSR, and Central Asia, China, Nepal, Korea, Taiwan, Pakistan, India, Bangladesh, Burma, Malaysia, Indonesia, Philippines, Thailand, southern Vietnam, Sri Lanka, Java, Timor, and Papua New Guinea. Though this species is considered to be a minor pest of sugarcane at Ramu (PNG), it has the potential of causing high degree of damage to Australian cane in the case of an incursion, particularly where competing species are not present.

3.1.3 Borer *Chilo sacchariphagus* (Bojer)

This species is a major pest of sugarcane in China, India, Indonesia, Madagascar, Mauritius and Taiwan. It also occurs in Reunion and the Comoros, Borneo, Java, Bali, Sumatra, Celebes, Japan, Singapore, Sri Lanka, Malaysia, Thailand and the Philippines, and has recently invaded the African mainland. *C. sacchariphagus* also attacks sorghum and is considered to be one of its important pests in some parts of China. This species is often treated as three subspecies: *C. s. stramineellus* (Caradja), *C. s. sacchariphagus* and *C. s. indicus* (Kapur), but the status of these is unclear. *C. sacchariphagus* infests the plant when they start forming internodes until harvest time. The incursion potential of *C. sacchariphagus* into Australia is medium to high, and the pest would have a high spread and colonisation potential in all sugarcane-growing areas.

3.1.4 Borer *Chilo terrenellus* Pagenstecher

This species is native to Papua New Guinea where it is a significant pest of sugarcane in the Markham Valley and at Ramu. *C. terrenellus* has been recorded in Australia on the Torres Strait islands of Saibai and Dauan. The probability of this species invading commercial areas in Australia is high.

3.1.5 Borer *Chilo tumidicostalis* (Hampson)

This species is reported to feed exclusively on sugarcane. It is found in Bangladesh, Burma, India (Assam and Bengal), Nepal and Thailand. Severe outbreaks were reported in the provinces of Sa Kaew and Buri Rum in Thailand where infestation reached 100%. The incursion potential of *C. tumidicostalis* into Australia is medium, due to its relative isolation from the mainland. However, the pest would have a high spread and colonisation potential in sugarcane-growing areas especially in northern Queensland.

3.2 Genus *Diatraea*

This genus is extremely close to *Chilo,* but occurs only in North and South America. *Diatraea* and *Chilo* form a compact monophyletic group, and appear to be kept as distinct genera mainly for practical purposes. This genus contains 35 species, in which *D. saccharalis* and *D. considerata* are the most important on sugarcane. The remainder of the species may pose a minor to negligible degree of threat to sugarcane crops.

Diatraea saccharalis is found in from the southern USA, through central America and the Caribbean and into South America as far south as northern Argentina, and is principally a pest of sugarcane but also recorded on other gramineous hosts. *D. considerata* is mainly a pest of sugarcane, and it is found in Mexico and Venezuela.

3.3 Genus *Eldana*

This genus contains only one species (*E. saccharina*), which is indigenous to Africa, where it is recorded in Angola, Benin, Burundi, Botswana, Cameroon, Chad, Congo, Ghana, Ivory Coast, Kenya, Mozambique, Nigeria, Rwanda, Sierra Leone, Somalia, South Africa, Tanzania, Uganda and Zambia. *E. saccharina* has the potential to cause severe losses to Australian sugarcane in case of introduction. However, the incursion potential of *Eldana* into Australia is medium due to its geographical isolation.

3.4 Genus *Sesamia*

Literature searches identified nine species of *Sesamia*, and all have the potential to cause a degree of damage to sugarcane if introduced into Australia. These are: *S. arfaki*, *S. calamistis*, *S. cretica*, *S. grisescens*, *S. inferens*, *S. nonagrioides*, *S. penniseti*, *S. peophaga* and *S. uniformis*. Of these, *S. grisescens* is considered to be the most likely borer to be introduced into Australia due to its geographical situation and severity of damage recorded in its native home (Papua New Guinea). This species would be capable of causing significant damage to the Australian sugar industry in the case of an incursion.

3.4.1 Borer *Sesamia grisescens* Warren

This species is restricted to its native home (Papua New Guinea). It became a major pest of sugarcane at Ramu when they changed to varieties that were resistant to Ramu Stunt but *Sesamia*-susceptible. At Ramu, estimated losses are 0.82 tonnes of cane per hectare, 0.13 tonnes of sugar per hectare and 0.15% pol for every 1% of bored and rotting stalks, making this species the most important borers with the potential to invade Australia. *S.*

grisescens has a high entry potential into Australia, and will have a high colonisation potential in all Australian sugarcane-growing areas, especially in northern Queensland.

3.4.2 Borer *Sesamia inferens* Walker

This species is a notorious pest of sugarcane in Okinawa Prefecture in Japan and an important pest of rice in the Indian subcontinent, and it has a high potential to colonize many parts of Australia in case of incursion. However, it is difficult to estimate the level of damage it may cause and the host plants that it will attack in Australia, since it appears to only cause minor damage to cane plantations in South East Asia.

3.5 Genus *Scirpophaga*

This genus contains 35 species, with *S. excerptalis* being a major pest of sugarcane in Asia, and *S. magnella* recorded feeding on sugarcane in Bangladesh and Pakistan. Other species in this genus are pests of other crops, such as *S. innotata* and *S. nivella* on rice. One important outcome of this project is that we confirmed the findings of Lewvanich in 1981, who stated that *S. nivella* is not a pest of sugarcane, but rather a pest of rice. Mohamed Sallam and Keith Chandler (BSES Limited) collected adult moths from southern Sumatra during a consultancy trip to Gula Putih Mataram plantation in Indonesia in June 2003, and these were identified by ED Edwards as *S. excerptalis*, though the pest is still referred to as *S. nivella* in Indonesia and many other Asian countries.

3.5.1 Borer *Scirpophaga excerptalis* Walker

This species is found in Bangladesh, Bhutan, China, India, Indonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, PNG, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam. *S. excerptalis* is mainly a pest of sugarcane, and causes significant damage to sugarcane in several countries of South East Asia. It is important to realize that this species has for a long time been erroneously referred to as *Scirpophaga nivella*. The confusion in the identity of *S. excerptalis* and *S. nivella* was resolved by Lewvanich (1981), yet many recent references still refer to *S. nivella* as a pest of cane in Asia. As mentioned before, Sallam and Chandler collected adult moths from cane plantations in Southern Sumatra - Indonesia, in June 2003, and these were confirmed as *S. excerptalis*.

S. excerptalis has a high entry potential into Australia, and a high colonisation potential in all Australian sugarcane-growing areas.

3.6 Other genera

During our literature search, we came across references to a number of other borer species that were not considered in the work proposed for this project. They, however, warrant mentioning here, due to their relative importance in sugarcane:

- *Angustalius* (*Bleszynskia*) *malacellus* Duponchel (Lepidoptera: Crambidae).
- *Acigona steniellus* (*Bissetia steniella*) Hampson (Lepidoptera: Pyralidae).
- *Emmalocera* (*Polyocha*) *depressella* Swinhoe (Lepidoptera: Pyralidae).
- *Maliarpha separatella* Ragonot (Lepidoptera: Pyralidae).
- *Tetramoera* (*Argyroploce*) *schistaceana* (Snellen) (Lepidoptera: Tortricidae).

4.0 IDENTIFICATION OF LARVAE

The Australian sugar industry has determined that the accurate and rapid identification of borer larvae is a biosecurity priority (Allsopp *et al.* 2001). The correct identification of an incursion species is critical to framing the correct responses. Larvae of many species are impossible to separate morphologically. The most reliable identification is based on adults, especially through male genitalia; this requires that suspect larvae are reared to adults, a process that is time consuming and may result in few adults or adults of the wrong gender.

Alternative very reliable and rapid methods are based on DNA analysis; these can be used to identify any life stage. We obtained borer specimens from overseas contacts, as well as native lepidopterous larvae associated with sugarcane in Australia. Australian material was identified by Peter Allsopp, while overseas material was identified by sugarcane entomologists in the respective country. Twenty-six taxa from 10 genera were included. In conjunction with the Centre of Identification and Diagnostics (CID) at University of Queensland, we sequenced the COII and 16S mitochondrial DNA genes of all these species. Full methods and results are given in the manuscript in Appendix 2.

The data have allowed an analysis of the current phylogeny of this diverse group. The Noctuidae were found to be monophyletic, suggesting a robust taxonomy within this subfamily. However, the Pyraloidea were paraphyletic, with the noctuids splitting the Crambinae from the Galleriinae and Schoenobiinae. This supports the separation of the Pyralidae and Crambinae, but does not support the concept of the incorporation of the Schoenobiinae in the Crambidae. Of the three crambine genera examined, *Diatraea* was monophyletic, *Chilo* paraphyletic, and *Eoreuma* was basal to the other two genera. Within the Noctuidae, *Sesamia* and *Bathytricha* were monophyletic, with *Busseola* basal to *Bathytricha*. Many species in this study (both noctuids and pyraloids) had different biotypes within collection localities and across their distribution; the former were not phylogenetically informative. These data highlight the need for taxonomic revisions at all taxon levels.

The data also provide a basis for DNA-based diagnostics. The project proposal envisaged that DNA sequences would be screened for diagnostic restriction-endonuclease cut sites, and enzymes that yield possible diagnostic RFLPs would be identified. Those that produce diagnostic markers would then be selected for diagnostic use based on their reproducibility and robustness. Our analysis of the mDNA data showed that this would be impractical and that direct sequencing of COII and/or 16S mDNA would yield better identification for two reasons:

- the number of RFLPs needed to accurately separate the large number of potential identifications is reasonably large –direct sequencing would be faster than carrying out the sequential series of RFLPs to identify specimens to species level;
- direct sequencing will give information not only on the species identification, but can also differentiate between material/biotypes from different areas.

The capability for DNA identification of borers has been transferred to BSES Indooroopilly for use when necessary. There is also potential for adding further species to the database as they become available through personal contacts– some have been received in the last few weeks.

5.0 PHEROMONE-BASED DETECTION

Pheromone traps are widely used in biosecurity programs for the early detection of incursions. They offer a simple method of collecting male moths that does not require external power sources, and so can be used in remote locations, and that can be maintained by relatively untrained personnel. Similar attractant traps are used by the Northern Australian Quarantine Strategy (NAQS) to detect pest incursions across northern Australia, especially the Torres Strait islands.

Before such traps can be deployed they need to be field tested to determine if trap catches are likely to be 'contaminated' with native species that might 'disguise' target-species catches, and to detect any problems in use at remote locations. We tested these in a trial across Queensland.

5.1 Materials and methods

Pheromone traps were placed at 11 locations across Queensland, including some Torres Strait islands:

1. Brisbane – BSES Indooroopilly. Adjacent to golf course and BSES glasshouse facilities.
2. Bundaberg – Farm of L Rasmussen, Ten Mile Road, Sharon. Adjacent to treed area with grass and gully with a creek nearby. Cane cultivar Q138.
3. Mackay - BSES station at Te Kowai. Field contained a high early sugar trial with 34 clones, but traps were hung in the outside row (a single guard row of Q185$^{(b}$).
4. Burdekin - BSES Station at Brandon. A mixture of cultivars.
5. Herbert – Farm of D Copley, Hawkins Creek. Paddock adjacent to the creek and bordering the forest; with a mixture of cultivars but mostly Q124.
6. Tully – BSES station at Tully. Area surrounded by thick forest, in a second ratoon Q174$^{(b}$.
7. Innisfail - Adjacent to South Johnstone River. Paddock surrounded by abundance of wild grasses and close to rainforest; a mixture of cultivars, but mostly Q166$^{(b}$ and Q172$^{(b}$.
8. Mulgrave – Farm of R Dowling, Green Hill. Paddock close to the hill, in an area west of Yarrabah National Park; a mixture of cultivars (Q174$^{(b}$, Q166$^{(b}$ and Q138).
9. Mossman – Farm of A Puglisi, Miallo. Paddock backing onto Daintree rainforest; first-ratoon crop of Q186$^{(b}$.
10. Tableland – Farm of P Byrnes, Walkamin. Area close to water supply channel; fairly new area to sugarcane (cleared grassland).
11. Torres Strait Islands – With assistance from NAQS traps were deployed on Yam, Hammond, Stephen and Mer Islands, but catches were only recorded from Mer. Traps targeted locations close to cane planted in back yards or established gardens, sites in Hammond Island had cassava plants, and *Terminalia catappa* trees near a gully.

Pheromones for the Asian stalk borers (*Sesamia grisescens*, *S. inferens*, *Chilo suppressalis*, *C. auricilius*, *C. infuscatellus* and *Scirpophaga excerptalis*) were obtained from Richard Vickers, CSIRO Entomology, Indooroopilly. Those for American species (*Diatraea considerata*, *D. impersonatella*, *D. grandiosella*, *Elasmopalpus lignosellus*, *Eoreuma loftini*) were obtained from Cam Oehlschlager, ChemTica, Costa Rica. We could not access some of these until mid-late 2002, hence they were tested only in early 2003.

Traps used were simple delta traps with sticky inserts where the pheromone pellet is placed. The traps were tied to cane leaves about 1-1.5m above ground level using a wire (Figure 5), and distributed 20 m apart within the field. One trap of each type was placed at each location. Fields close to rain forest (specially in North Queensland), or fields surrounded by an abundance of wild grasses or along river banks were targeted. Trapping commenced in January 2003 and ceased at the end of June 2003; traps were monitored each 7-14 days and moths removed. All moths captured were identified by ED Edwards, CSIRO Entomology, Canberra.

Figure 5 Pheromone trap in place in sugarcane field

5.2 Results and discussion

Problems encountered during trapping were:

- Numbers written on traps washed off in the rain, even when a 'permanent' marker was used; this was overcome by writing the trap number on the inner side of the trap as well as on the underside of the inserts.
- Catches were attacked by ants; this was overcome by more frequent replacement of inserts to ensure that the glue remained fresh.
- In some cases, the pheromone pellets were chewed by ants; old inserts were replaced and new pheromones attached.
- Lodging of cane forced us to move the traps to other standing cane plants.
- Removal of attracted moths using xylene or kerosene damaged them; more inserts were ordered so that the whole insert is replaced with a new one and the moth stays intact.

- In two cases, one in Mossman and in Greenhill, the trap baited with the *Sesamia grisescens* pheromone was attacked by dingos; traps had to be replaced.
- Some farming practices such as field irrigation or headland slashing damaged some traps; traps were moved one row into the paddock instead of the edges and damaged traps were replaced with new ones.
- No data were available from the Mossman site although it had the traps for the same period of time (February-July 2003); heavy rainfalls disrupted sampling several times and damaged trap inserts, and this made it unfeasible to identify the catches. Similar problems occurred at Mulgrave and Tully, where due to heavy rain and severe lodging some traps could not be recovered towards the end of the season, and some inserts had accumulated mud that made catches difficult to identify. However, every effort was made to specially collect and preserve any macro-lepidoptera for possible identification.

Trapping results are shown in Table 1. No exotic species were found in any of the traps and all of the collected moths were readily separable from pestiferous stemborers. Several insect taxa were attracted to the pheromone lures, most probably by accident. However, only those belonging to Lepidoptera (moths) were collected and retained for identification. Although many insects appeared to have been accidentally trapped, we believe that some were probably attracted in response to the pheromone. A clear example is the attraction of several *Margarosticha sphenotis* adults to the *Sesamia inferens* pheromone (Figure 6) on two separate dates at the Tableland site. Similarly, the *Scirpophaga excerptalis* pheromone seems to have more frequently than chance attracted several insects at many locations. The *Eoreuma loftini* pheromone did not attract any moths in any of the locations except for Indooroopilly, where a few of the very common *Herpetogramma licasisalis* were captured, probably by accident.

Figure 6 ***Margarosticha sphenotis*** **moths in a** ***Sesamia inferens*** **pheromone trap**

NAQS were involved in the deployment of traps on Mer Island. Both they and NorthWatch (QDPI) have been shown the results and will consider further deployment of traps.

Table 1 Moths attracted to pheromone lures of exotic borer species

Trap	Location									
	Indooroopilly	**Bundaberg**	**Mackay**	**Burdekin**	**Ingham**	**Tully**	**Innisfail**	**Mulgrave**	**Tableland**	**Mer Island**
Sesamia grisescens	**24/3; 14/4; 27/5; 12/6/03** 3 *H. licasisalis*			**19/2/03** 1 *Opogona* sp. 1 Pyralidae (Phycitinae)	**18/2/03** 3 Gelechioidea **27/5/03** 1 Gelechioidea					
Sesamia inferens	**10/3/03** 3 Cosmopterigidae				**18/2/03** 3 Gelechioidea **5/3/03** 2 Gelechioidea		**6/2/03** 1 Gelechioidea **20/2/03** 4 Gelechioidea		**2/5/03** 2 *M. sphenotis* 1 Noctuidae 1 Hadeninae **17/7/03** 9 *M. sphenotis* 1 *Opogona* sp.	**9/4/03** 3 Pyralidae (Phycitinae)
Chilo suppressalis	**14/4/03** 2 *H. licasisalis*	**14/2/03** 15 Gelechioidea **25/2/03** 3 *Opogona* sp. 11 several species of Gelechioidea		**19/2/03** 6 *S. hemiopthalma* 1 *Opogona* sp. **3/4/03** 5 *S. hemiophthalma* 1 Cosmopterigidae 1 *Opogona* sp.	**28/4/03** 6 *S. hemiopthalma* 1 Lecithoceridae **21/5/03** 1 *S. hemiophthalma* 1 *Opogona* sp.			**26/3/03** 13 Gelechioidea 3 *S. hemiopthalma* **4/5/03** 11 *S. hemiophthalma*	**1/4/03** 7 *S. hemiophthalma* 1 *Opogona* sp.	
Chilo auricilius	**24/3; 27/5/03** 3 *H. licasisalis*			**3/4/03** 1 Cosmopterigidae 1 *Opogona* sp. 1 Gelechioidea	**18/2/03** 1 Lecithoceridae	**26/3/03** 2 *Luceria* sp.	**2/6/05** 1 *Opogona* sp.		**13/5/03** 1 Cosmopterigidae 2 Gelechioidea 2 Pyralidae	
Chilo infuscatellus	**24/3/03** 1 Pyralidae				**21/5/03** 1 *Glaucocharis* sp. 1 *S. thodinastis*		**8/4/03** 1 *S. thodinastis*			
Diatraea considerata							**20/5/03** 1 Hesperiidae **2/6/03** *Opogona* sp.			**9/4/2003** 1 Gelechioidea
Diatraea impersonatella	**28/4; 14/5//03** 2 *H. licasisalis*									
Diatraea grandiosella	**14/5/03** 2 *H. licasisalis*			**19/2/03** 3 *S. hemiophthalma*			**20/5/03** 1 Pyralidae			

				2 *Opogona* sp. **3/4/03** 3 *S. hemiophthalma* 1 Cosmopterigidae 1 *Opogona* sp.						
Scirpophaga excerptalis	**14/4; 27/5; 12/6/03** 3 *H. licasisalis*		**19/2/03** *S. hemiophthalma*	**19/2/03** 10 *S. hemiophthalma* 1 *Opogona* sp. 1 Gelechioidea **3/4/03** 10 *S. hemiopthalma*	**18/2/03** 1 *S. hemiophthalma* **8/4/03** 4 *S. hemiophthalma*	**19/2/03** 3 *S. hemiophthalma* **26/3/03** 2 *S. hemiophthalma* 1 Gelechioidea	**20/2/03** 2 *S. hemiophthalma*	**4/2/03** 1 *S. hemiophthalma* **26/3/03** 2 Gelechioidea 1 *S. hemiophthalma*		
Elasmopalpus lignosellus	**28/4; 2/5/03** 2 Cosmopterigidae **14/5/03** 1 *H. licasisalis*				**27/5/03** 1 *Opogona* sp.	**29/4/03** 1 *H. licasisalis*	**20/5/03** 1 Arctiidae	**26/3/03** 4 Gelechioidea		
Eoreuma loftini	**14; 12/5/03** 11 *H. licasisalis* 1 Oecophoridae									

- *H. licarsisalis* = *Herpetogramma licarsisalis* (Walker) (Lepidoptera: Pyralidae), an Australian native pest of pasture known as the sod webworm or grass caterpillar.
- *Opogona* sp. (Lepidoptera: Tineidae).
- *Luceria* sp. (Lepidoptera: Hypenodinae: Noctuidae)
- *S. hemiophthalma* = *Sufetula hemiophthalma* (Lepidoptera: Pyraustinae: Pyralidae).
- *M. sphenotis* = *Margarosticha sphenotis* (Lepidoptera: Nymphalinae: Pyralidae).
- *S. thodinastis* = *Synolulis thodinastis* (Lepidoptera: Hypenodinae: Noctuidae).

6.0 IMPORTATION OF NATURAL ENEMIES

Natural enemies, particularly insect parasitoids, are important components of control strategies used against exotic borers in most overseas industries. Understanding the suite of potential species is essential before any decision on important can be made. In addition, before a parasitoid can be imported into Australia, the native fauna of similar parasitoids needs to be understood and details of the host specificity of the imported parasitoid are required. However, no application for importation can be made until the target species exists in Australia.

A list of all natural enemies of gramineous stemborers in Asia and Indian Ocean islands recorded over the last century has been prepared; this is given in Appendix 3 as a manuscript submitted to the *Australian Journal of Entomology*. It lists more than 200 species of natural enemies recorded on 19 host species.

Based on that list and from discussions with overseas colleagues, *Cotesia flavipes* (Hymenoptera: Braconidae) stands out as the most efficient natural enemy of most of the key stemboring pests through the world. Some remarkable successes of the establishment of this species are reported (Polaszek & Walker 1991; Overholt *et al.* 1997), and it is commonly used in IPM programs for borer control (e.g. Kuniata 1999). The fairly wide host range of *C. flavipes* qualifies it to be a strong candidate in case of incursion of some of the most important borer species into Australia. However, any importation of this species into Australia can not proceed until the status of *Cotesia nonagriae* already present in Australia is clarified. *Cotesia flavipes* exists as a number of 'strains', and one Australian taxon has been synonymised under *C. flavipes.* Detailed examination of this problem was beyond the scope of the project, but Dr Sallam has been successful in obtaining Australian Research Council funds (in conjunction with Prof. Andy Austin, University of Adelaide) to determine the status of '*C. flavipes*' biotypes from around the world. This study will provide the basis for further consideration of the necessity for importation of *C. flavipes* and the best source for material.

It needs to be noted that, of 21 stalk borer species identified as posing different degrees of risk to Australia, two are not recorded as hosts of *C. flavipes*; these are *Sesamia cretica* and *Scirpophaga excerptalis*. Other natural enemies must be considered in case of incursion of any of these two pests. The most important parasitoids recorded on *Sesamia cretica* are *Platytelenomus busseolae* (Hymenoptera: Scelionidae), and *Habrobracon hebetor* (Hymenoptera: Braconidae) from Iran, and *Bracon brevicornis* (Hymenoptera: Braconidae) and *Meteorus rubens* (Hymenoptera: Braconidae) from Egypt. *Stenobracon deesae* (Hymenoptera: Braconidae), *Rhaconotus scirpophagae* (Hymenoptera: Braconidae), *Elasmus zehntneri* (Hymenoptera: Elasmidae) and *Isotima javensis* (Hymenoptera: Ichneumonidae) from India are some of the key parasitoids recorded on *Scirpophaga excerptalis* in Asia.

Another important parasitoid recognized from the literature survey was *Xanthopimpla stemmator* (Hymenoptera: Ichneumonidae), a pupal parasitoid that has a different attack strategy (drill and sting) to *Cotesia* (ingress and sting) (Smith *et al.* 1993). *X. stemmator* is recorded on seven key borer species that are considered to be of high to medium threat to Australia, and will only attack borers that are concealed in a stem, and this implies some degree of specificity. The parasitoid is also capable of colonizing a wide range of habitat and has a fairly wide geographical distribution. It is not known from Australia.

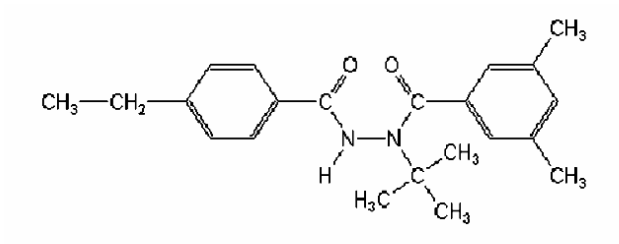
7.0 EMERGENCY-USE PERMITS FOR INSECTICIDES

When the project proposal was framed, we were of the opinion that the National Registration Authority (now Australian Pesticides and Veterinary Medicines Authority – APVMA) would consider an application for a proactive emergency-use permit for the use of a named insecticide against sugarcane stemborers. However, in subsequent discussions with APVMA staff (Alan Norden – Permits Coordinator), it was made clear to us that APVMA can not consider a permit unless it addresses a specific pest that is present in Australia. Their advice was to prepare a dossier of supporting information for any prospective insecticide, which would be ready to support any permit application once an incursion occurred. This would dramatically reduce the time between detecting the incursion and having permission to use the insecticide.

We searched the literature and spoke to overseas colleagues to identify suitable insecticides that could be used to manage a stemborer incursion. We identified two chemicals that are used overseas against stemborers: tebufenozide (Mimic®, Confirm® or RH-5992) and lambda-cyhalothrin (Karate®). Dossiers on each have been prepared (Allsopp 2001; Sallam 2002).

7.1 Tebufenozide

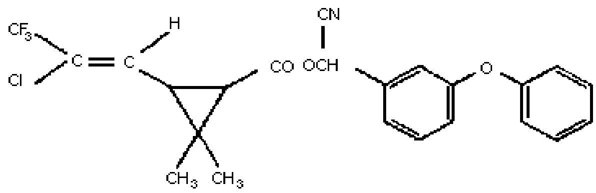
Tebufenozide (3,5-dimethylbenzoic acid 1-(1,1-dimethylethyl)-2-(4-ethylbenzoyl) hydrazide) is an ecdysone agonist that acts by binding to the ecdysone receptor protein. The moulting process of treated insects is lethally accelerated, especially in lepidopterans (moths, caterpillars). It is non-phytotoxic to sugarcane and shows little negative effect on populations of stemborer parasitoids and other beneficial insects. It is registered for use in USA against *Diatraea saccharalis* and has been used successfully in Papua New Guinea against *Sesamia grisescens*. The product is manufactured by Rohm and Haas and marketed in Australia by Bayer Australia.



7.2 Lambda-cyhalothrin

Lambda cyhalothrin (alpha-cyano-3-phenoxybenzyl-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethyl-cyclopropane-carboxylate) is a pyrethroid insecticide and acaricide used to control a wide range of pests in a variety of applications. Pests controlled include a range of sugarcane stemborers such as *Sesamia grisescens* in Papua New Guinea, *Eldana saccharina* in South Africa, *Busseola fusca* in Ethiopia, *Chilo partellus* in Pakistan and

Ostrinia nubilalis in Poland. Lambda cyhalothrin is available as an emulsifiable concentrate, wettable powder or ULV liquid, and is commonly mixed with buprofezin, pirimicarb, dimethoate or tetramethrin. The product is marketed by Syngenta.



8.0 AWARENESS AND RESPONSES

8.1 Awareness

We first conducted a wide awareness campaign targeting a wide range of industry personnel. Several sessions were held and were mainly attended by canegrowers along with representatives from chemical and agricultural supply companies, cane productivity services, CANEGROWERS and others. The campaign was linked to activities within the already existing *GrubPlan* program, and a short presentation was given by Dr Sallam at each *GrubPlan* session with the aid of a poster. The poster showed the type of damage inflicted by *Sesamia grisescens*, photos of early instar larvae in the growing point of the plant, and the pest's life cycle.

On 5 December 2001, a meeting was held at BSES Meringa to discuss pest problems in far-northern areas. The meeting was attended by a number of Mulgrave canegrowers, BSES extension officers from Innisfail, representatives from the Mulgrave mill and three BSES entomologists (Allsopp, Sallam and Chandler). Dr Allsopp gave a presentation on the borer incursion project as a first step towards the awareness campaign. Roles of different organizations in the project and what is expected from farmers were highlighted. A clear message was conveyed to farmers during the meeting to immediately report any sign of boring activity in cane, while no infested material should be moved.

A series of sessions were held during March-April 2003 in the Herbert (10 growers), Mareeba (8 growers), Tully (25 growers), Innisfail (27 growers) and Meringa (16 growers). In addition, a presentation at a COMPASS workshop was given by Dr Sallam on 14 March 2003 at the CANEGROWERS office in Gordonvale where 13 Mulgrave growers attended. Another presentation took place during a Plant Pathology day at Meringa held by Rob Magarey and the Tully Plant Pathology team on 14 May 2003, which tied in with a presentation given by Magarey on the Smut Contingency Plan. All the previously mentioned sessions were attended by representatives from different organizations, i.e. BSES extension officers, cane productivity services, mill workers, Bayer, Crop Care and Grow Force staff. Growers showed high interest in the information presented and interactively asked questions. The most commonly asked questions were: 'How can infestation be detected?', 'What does the moth/larva look like?', and 'Were any exotic species caught in the pheromone traps?'.

Finally, a quarantine forum took place on 7 May 2003 during the 25th ASSCT conference in Townsville. The forum derived from a meeting held in Brisbane that was facilitated by Plant Health Australia (PHA) and BSES on 17 October 2002, and that was attended by representatives from CANEGROWERS, QDPI, AQIS, AgWest, Mossman Mill and the Office of the Chief Plant Protection Officer (OCPPO). At that meeting, the need arose for a more defined role for the different organizations regarding the preparedness for borer incursion. At the quarantine forum, Drs Sallam and Allsopp presented an overview of the work done by BSES through the project, and Judy Grimshaw (NAQS-AQIS) gave a presentation on the work done through the NAQS program, and cooperation with BSES in this project. Barry Croft (BSES) discussed the recent changes to the *Plant Protection Act.* Ron Kerkwyk (Herbert CPS) facilitated a discussion on the role of cane productivity services in plant inspection, highlighting the importance of looking out for symptoms of stalk borers and smut in addition to other endemic pests and diseases. The meeting was attended by a total number of 40 people representing cane productivity service staff and a number of growers, along with representatives from QDPI, Plant Health Australia and CANEGROWERS. Attendees included BSES' CEO and R&D Manager. The industry's response was tested during these sessions and a positive outcome was recognized. Ron Kerkwyk confirmed CPSs' commitment to routine surveys, as well as their readiness to be involved in emergency response surveys in case of incursion.

8.2 Testing responses

Extensive discussions between BSES, CPPO, QDPI, PHA and AQIS took place over the period June-August 2003 prior to initiating a simulation exercise. The exercise was delayed until after that because of the on-going discussions between PHA, governments and industry on a cost-sharing arrangement for dealing with incursions; this has still not been resolved. The discussions aimed at informing other organizations of the activities conducted by BSES thus far, and to facilitate communication between the different organizations with regards to quarantine measurements. The discussions helped all organizations to learn about the specific roles of each other and how we could all combine efforts in case of incursion. Most importantly, the discussions established a base upon which a simulation of incursion could be initiated.

On 12 September 2003, a phone conference was held between Dr Graeme Hamilton (CPPO - AFFA), Dr Peter Allsopp (BSES - Manager Special Projects), Rodney Turner, Clare Duncan and Caitlin Johns (Plant Health Australia), Russell Gilmour (APHS - QDPI), Bonny Vogelzang (NorthWatch, QDPI), Alan Rudd (Mossman Agricultural Services), Mohamed Sallam and Keith Chandler (BSES entomologists), and David Calcino (BSES Regional Manager). During the conference, we simulated an incursion of an exotic borer to test our preparedness at both industry and national level. BSES defined the assumptions behind the exercise as:

1. A hypothetical infestation of a particular stalk borer species is detected on mainland Australia. *Chilo auricilius* was chosen as the pest for a number of reasons:
    a. Geographically close to Australia.
    b. Has a wide host range (sugarcane, rice, corn and sorghum) so an incursion would involve the grains industry.
    c. Very similar morphologically to *C. polychrysus,* which is confirmed in Australia.

   d. A devastating insect in India and Indonesia with a clear impact on yield and CCS, though not so in PNG where it is a minor pest of rice.

2. The hypothetical infestation is detected in a certain area. More than one scenario is proposed:
   a. A few stalks chewed by larvae in Mossman.
   b. Heavy infestation reported in one field at Mossman.
   c. Three plots reported the presence of infested stalks, two in Mossman, and one in Mareeba (Tableland).
   d. Heavy infestation in a number of fields in Mossman and the Tablelands.

The aim of the conference was to test preparedness to quickly respond to any of these scenarios.

Turner first discussed the pest categorization that will form part of the cost-sharing agreement. PHA is in the process of approaching all plant industries in Australia to nominate five exotic pests that need to be recognized and 'categorized'. Pest Categorization is a first key step in deciding on a cost-sharing agreement between the government and the affected industry(s) in case a pest invades the country. PHA is sending out a Position Paper to all plant industries in Australia. PHA management will be visiting all of their members prior to their AGM in October to carry out this process. In the case of the sugar industry, the Position Paper will be sent to CANEGROWERS as they are PHA members, however, BSES will also be involved to give technical input; CANEGROWERS have nominated Allsopp, Sallam, Croft, Magarey and Milford as contacts. The Pest Categorization will be based on eight questions in the questionnaire to be filled out by entomologists and plant pathologists, and these answers will be used to place the pest in a category that will warrant a particular cost-sharing arrangement in the case of an incursion.

Hamilton indicted that the establishment of a cost-sharing agreement will be predicated on the existence on a formal Biosecurity Plan that defines the key threatening pests and diseases; both Turner and Allsopp confirmed the existence of a partially developed and detailed Biosecurity Plan for the sugar industry. Hamilton explained the role of the Consultative Committee on Exotic Plant Pests (CCEPP), which is the committee that convenes once an incursion is detected in any part of the country. The Consultative Committee involves members who would make funds available for the eradication campaign (basically representing the Commonwealth government, the State and Territory governments and the affected industry(s)). The committee examines all available information on the pest or disease and confirms if it is actually exotic, examines its current distribution, whether eradication is feasible, and if it is worth eradicating. The CCEPP will receive diagnostic information from an ad hoc committee, which will be formed specifically for the purpose of providing the technical information on the introduced pest/disease and report to the CCEPP. The CCEPP then puts the recommendations to a National Management group, formed of CEOs of various Commonwealth agencies, State agriculture departments and the industry body (which in this case will be CANEGROWERS). The National Management Group will make a decision whether the pest/disease should be eradicated or not and report back to the CCEPP. If the decision is to eradicate the pest, then the State agriculture department (QDPI in case of Queensland) will be the lead agency in undertaking the eradication and will report back to the CCEPP on how the process of eradication is going. Hamilton also indicated that eradication is normally tried first, and, based on the progress report over a period of time, the situation is reassessed and a decision whether to continue with the eradication campaign (if the CCEPP believes the pest can be eradicated), or to 'contain' the pest will be made. Therefore, under any of the four incursion scenarios proposed for this exercise, an eradication campaign will be initiated first; if that has apparently failed, then a decision to contain the pest will be made if the CCEPP believes the pest is not eradicable, and efforts should be focused on minimizing its impact on the industry or the community.

Gilmour outlined the role of Animal & Plant Health Service (APHS - QDPI), and he indicated that the Chief Plant Health Officer (CPHO), who is the General Manager of Plant Health (Chris Adrianson), is the one to be contacted in case of incursion in Queensland. CPHO establishes a local Pest Control Centre in the area in which the outbreak is, as well as a State Pest Control Centre in Brisbane. The General Manager of Plant Health will invite BSES and CANEGROWERS to participate in the local pest control centre, which is responsible for the delimiting surveys that follow an incursion, as well as directing the eradication campaign, and will report back to the State Pest Control Centre. In addition, APHS carries out technical training in the areas of plant and animal health. It also tests its ability to deal with an incursion through regular emergency response exercises.

Vogelzang outlined the role of DPI's NorthWatch, which was established in 1998 in Cairns, and mentioned three main activities they are involved in: early warning surveillance, response, and building emergency response capability. NorthWatch works closely with AQIS through the NAQS program, as well as other plant and animal health services. NorthWatch has five plant health scientists in Cairns, and do surveys in the Cape York Peninsula. NorthWatch also develops contingency plans and works closely with a number of industries in the north to promote their biosecurity planning.

Alan Rudd from Mossman Agricultural services indicated that they are involved in surveys and cane inspections. They are locally based on the mill area of Mossman and they have long experience in plant inspection. It had been confirmed through several meetings with various CPSs that there is good preparation on an industry level to quickly respond to an incursion, but we needed to confirm that they would be prepared to contribute manpower, and, at least initially, carry these costs. If the exotic pest (or disease) has been categorized, then the eradication cost would have been agreed upon. If not, then a categorization should be done promptly; in the meantime, an industry-government split would be 50-50. States will pay their share of the 50% proportion based on the gross value of production in each state of the particular product affected by incursion; therefore, in this case, the State of Queensland will mainly pay the bulk of the 50% for an eradication campaign of an exotic sugarcane pest, while the industry will pay the other 50% of the cost. All costs are signed off by Primary Industry Standing Committee.

Sallam mentioned that it is important to decide, in advance, on the staff that will form the Strategic Management Group that will operate in the area of incursion. Gilmour indicated that the APHS Regional Manager is the one to chair that committee and it reports to the General Manager of Plant Health. However, based on previous discussions with DPI, Allsopp mentioned that, for sugarcane, the Strategic Management Group has the local

Regional Manager of BSES as chair. Following corporatisation of BSES, this needs to be clarified.

This discussion was necessary for all conference participants to recognize the role performed by each organization.

8.3 Simulation exercise

Following the previous discussions, the simulation of incursion exercise was initiated with the assumption that an exotic cane borer was detected in Mossman. Participants indicated their immediate response and actions as follows:

- Rudd indicated that Mossman Agricultural Services (MAS) would inform BSES of a suspect incursion.
- Sallam indicated that he checked and confirmed the presence of an exotic cane borer in Mossman, and immediately informed BSES Head Office.
- Allsopp indicated that he reported to BSES CEO, who informed APHS and the CPPO, and this triggered the following chain of events:
- APHS would form a State Pest Control Head Quarters Committee, and invite BSES and CANEGROWERS to be a part of that committee; they will ask for a local pest control centre to be formed in the incursion area (BSES and MAS representatives). APHS will also inform the minister and there would be a press release.
- MAS would be involved in the surveys that will follow detection.
- Vogelzang (NorthWatch) would act as another agency to assist in the delimiting surveys.
- Hamilton would inform his minister when the Queensland minister is informed, then a Consultative Committee meeting would be convened as soon as possible. Meanwhile, he would wait for further information from Queensland regarding the situation of the pest and identity confirmation, and would gather all available information on that pest (using the PIMP as the basis). In addition, the CPPO would inform other parts of AFFA such as AQIS and BioSecurity Australia to establish a Task Force to deal with the incursion pending information collected by the Strategic Management Group.
- Sallam would immediately try to identify the pest to the species level with help from BSES Indooroopilly, Centre for Identification and Diagnostics (CID) or CSIRO Entomology, then convene the Strategic Management Group that will conduct extensive delimiting surveys with assistance from APHS and NorthWatch, then report survey results to the CCEPP.

The simulation exercise was followed by a discussion and the following key points were highlighted:

- The CPPO mentioned that it is much easier for AFFA to be informed through QDPI to avoid unnecessary multiple communication and possible confusion.
- Vogelzang inquired about the capability of pest identification and how we could quickly confirm its identity. Sallam indicated that BSES and CID have examined the DNA fingerprints and constructed a phylogeny tree for several borer species from overseas, and this should assist greatly in reducing the time needed to identify a new borer.

- Gilmour said that the *Queensland Plant Protection Act* defines the authority of imposing quarantine measures to be principally a DPI authority, and that the role of BSES needs to be confirmed, although some BSES staff are inspectors under the Act.
- Turner mentioned that Plant Health Australia are working on a document to be released soon detailing the reporting procedure. The document is meant to set standards to the reporting lines and time frames to be adhered to when reporting an incursion.
- Rudd confirmed that Mossman Agriculture Supplies are ready to conduct emergency response surveys anywhere in North Queensland and not only in the mill area of Mossman. He believes that this applies to other CPSs.
- Chandler highlighted the need for staff training to be able to conduct surveys and recognize an exotic pest or disease:
  - Hamilton commented that AFFA can assist in establishing an ad hoc group of technical experts to come up with standardized procedures of sampling and diagnosis and confirmation;
  - Sallam said that he is planning to approach agencies to fund a training package to target quarantine workers on the islands and Cape York Peninsula, as well as sugarcane workers especially in the north, on how to recognize exotic cane pests and diseases in particular;
  - Gilmour said that there will be a large number of roles involved when the Local Pest Control Centre is formed, and APHS will identify the workers to carry out the different roles which will include training. He also said that it would be very useful if APHS and BSES can jointly conduct a 'sugarcane oriented' training program. This has subsequently been planned for February 2004.
  - Clare Duncan (PHA) indicated that they have an emergency plan training program that will be carried out soon and will target people in local pest control centres.
  - Peter Allsopp said he will discuss training possibilities with Chris Adrianson (QDPI), meanwhile Sallam and Gilmour would work out a framework on how to locally go about training in the far north.

Based on the previous discussion and the chain of events that would be triggered following a report of incursion, we concluded that there is good preparation on both industry and national level to deal with incursion of an exotic pest in general, and a cane borer in particular. The major outstanding issue is the formation of the Strategic Management Group and who chairs it, and this will be sorted out in the near future following discussions between BSES and DPI.

The phone conference closed when all participant were satisfied with the process. Ties created between BSES, APHS, PHA and AFFA are most valuable and will prove very useful in case of a real incursion.

9.0 OUTPUTS

This project has greatly enhanced Australia's preparedness for an incursion of an exotic sugarcane borer, in particular, and a sugarcane pest in general, due to the following outputs:

- Comprehensive Pest Incursion Management Plans to deal with the incursion of borers from the genera *Chilo*, *Sesamia*, *Eldana*, *Diatraea* and *Scirpophaga*. These plans have been approved by industry organisations and are available on www.bses.org.au. The plans detail the steps to be taken in case of a borer incursion, and include extensive dossiers on each species with information on their distribution, host plants, symptoms, economic impact, morphology, detection methods, biology and ecology, natural enemies, management options and phytosanitary risk.

  These plans have already served as models for other plant industries in Australia to improve their preparedness for incursion of an exotic pest or disease. The plans also serve as an inclusive reference on all moth borers in the world, and thus provide an easily accessed reference to be referred to by anyone in Australia, or indeed the world, to enhance their knowledge on this group of pests. Most importantly, these plans will prove imperative when Plant Health Australia initiates the 'pest categorization' exercise, which is a prerequisite to reaching a cost-sharing agreement between the government and the industry if an incursion occurs.

- DNA-based technology developed for the accurate identification of 26 exotic species of borers belonging to 10 genera and 6 tribes in a cooperative study with the Centre for Identification and Diagnostics, University of Queensland. This methodology has been transferred to BSES where it will be available for any future use and for addition of other species. The method will reduce the time required to identify a borer species from weeks or months to days. The data also form a significant contribution to the understanding of the taxonomy of this group.

- Pheromone traps shown to be potentially useful for early detection of incursions. The trapping technology has been transferred to the Northern Australian Quarantine Survey (NAQS) and NorthWatch (QDPI) for possible deployment on a regular basis.

  Tests have indicated that all parts of Queensland are free of these borers. This conclusion is supported not only by pheromone trapping, but also by continuous surveillance and monitoring of cane paddocks by staff from BSES, Cane Productivity Services and other organizations. We have also listed the native moth species that will be attracted, accidentally or otherwise, to 11 pheromone lures of exotic borers. This information is useful to minimize confusion and speed up the identification process.

- A list of about 800 records of parasitoids, predators and pathogens of the 24 key moth borers in Asia and the Indian Ocean islands was compiled, with information on the host stage they attack, host plant or crop and country of record. This information will facilitate rapid decision-making regarding importation of a suitable natural enemy in case of a borer incursion. A significant outcome of this work was the development of a PhD project, through a link with Adelaide University, to look at the world (including Australian) population diversity of *Cotesia flavipes*. This species is a key parasitoid of stem borers, and strains suitable for borer control may already exist in Australia.

- Two insecticides that could be used in Australia against an introduced borer were identified. These are the ecdysone agonist tebufenozide (Mimic®, Confirm® or RH-5992) and the pyrethroid lambda-cyhalothrin (Karate®). Although emergency-use permits for off-label use in Australia could not yet be granted by the Australian Pesticides and Veterinary Medicines Authority, identification of these insecticides and the compilation of information to support their use against an incursion will minimize the time lost between detecting an exotic borer and use of the insecticide.

- A wide awareness campaign on procedures to follow if an incursion is suspected has been conducted. This targeted a wide range of industry personnel. Feedback was positive, especially with regards to the involvement of all Cane Productivity Services in regular routine surveys, and their willingness to be involved in emergency surveys if the need arises.

- An exercise to simulate an incursion was carried out to test preparedness at both industry and national level. We concluded that we are prepared to quickly respond to an incursion, and that an eradication campaign can be activated within a few days after detection.

- The creation of strong ties between different organizations, such as QDPI - APHS, AQIS, NorthWatch, Plant Health Australia and AFFA, ensuring the efficiency of our capability to quickly and collectively react to an incursion.

10.0 EXPECTED OUTCOMES

Based on the work done in this project, and especially the simulation of incursion exercise that was conducted at the end of the project, we expect the industry to respond efficiently and promptly to an incursion of a sugarcane borer in particular, and any other pest or disease in general. We also believe that future work will see more collaboration between BSES and other organizations (AFFA, APHS, AQIS and NorthWatch) based on the close ties that were created during the period of this project.

We also expect to speed up the pest categorization process since all possible information on moth borers are now easily accessed. This will lead to quick decision making regarding cost sharing agreement between the Commonwealth and State governments and industry.

We also expect that a quick identification of any potential incursion will happen as a result of the extensive awareness campaign and the simulation of incursion that we conducted. This is a positive outcome and will help significantly reduce the risk of establishment.

In summary, we have:

- An industry and government that is better prepared to deal with an incursion of an exotic borer.
- An on-going commitment by all sectors of the industry to biosecurity.

- The basis for a wide biosecurity plan currently being developed by Plant Health Australia in conjunction with industry.

11.0 FUTURE NEEDS AND RECOMMENDATIONS

- Like all such plans, the incursion management plans need to be updated in about 5 years time. Plant Health Australia is well poised to co-ordinate this activity.
- The industry should ensure that the capability to identify suspect exotic borers is maintained and developed further if possible. BSES currently is the depository for this technology.
- Dossiers on potential insecticides need to be updated in 5 years time. BSES entomologists have the skills and linkages to do this. SRDC's support for Dr Samson to travel to an ISSCT Entomology workshop in November 2003 will allow him to develop personal contacts with other sugarcane entomologists.
- NAQS and NorthWatch must be encouraged to deploy pheromone traps as part of their normal activities. 'Lobbying' from industry organisations could help achieve this.
- The composition of the Strategic Management Group that will convene in the area of incursion and be responsible for the delimiting surveys that will follow needs to be defined. This will require negotiations between QDPI and BSES.
- The industry needs to maintain the current awareness and enthusiasm for dealing with suspect incursions. This will become increasingly difficult under on-going changes to industry structures and organisations. CANEGROWERS, BSES and PHA have important roles in this process.
- We recommend that the industry establishes a 'trust fund' that can be quickly accessed in case of incursion by an exotic pest or disease.
- There is need for a 'sugarcane-oriented quarantine program', especially in North Queensland. The program should target all sugarcane workers in all sectors of industry. A learning package can be produced that shows symptoms of exotic pests and diseases and how to compare those to symptoms of indigenous ones. The training package should also include information on cane plantations in south-east Asia with emphasis on programs in Papua New Guinea and Indonesia. This will include information on main production constraints and what programs are in place in these countries to manage them. Photographs of plantation systems, pest and disease damage, wild cane, wild grasses and wild habitats need to be included. This should link with the current ACIAR-funded project on the conservation of sugarcane germplasm in Australia, Papua New Guinea and Indonesia.

12.0 PUBLICATIONS ARISING FROM THE PROJECT

12.1 BSES reports

Allsopp PG. 2001. Summary of effectiveness of tebufenozide for control of sugarcane stemborers. *BSES Publication* PR01004.

Allsopp PG and Sallam MN. 2001. *Sesamia* incursion management plan - Version 1. *BSES Publication* PR01002.

Sallam MN. 2002. Summary of the effectiveness of lambda-cyhalothrin for control of sugarcane stemborers. *BSES Publication* PR02005.
Sallam MN & Allsopp PG. 2002. *Chilo* incursion management plan - Version 1. *BSES Publication* PR02008.
Sallam MN & Allsopp PG. 2002. *Eldana saccharina* incursion management plan - Version 1. *BSES Publication* PR02009.
Sallam MN & Allsopp PG. 2003. *Scirpophaga* incursion management plan - Version 1. *BSES Publication* PR03001.
Sallam MN & Allsopp PG. 2003. *Diatraea* incursion management plan - Version 1. *BSES Publication* PR03002.

All are available at www.bses.org.au.

12.2 Published papers

Allsopp PG, Sallam MN, Graham GC and Scott K. 2001. Minimising the threat of lepidopteran borers to the Australian industry. *Proceedings of the International Society of Sugar Cane Technologists* 24: 389-391.
Sallam MN & Allsopp PG. 2002. Preparing for borer incursion into Australia. *Australian Sugarcane* 5(6): 5-7.

12.3 Submitted manuscripts

Lange CL, Scott KD, Graham GC, Sallam MN and Allsopp PG. Sugarcane moth borers (Lepidoptera: Noctuidae and Pyraloidea): phylogenetics constructed using COII and 16S mitochondrial partial gene sequences. Submitted to *Bulletin of Entomological Research* (Appendix 2).
Sallam MN. A review of sugarcane stemborers and their natural enemies in Asia and Indian Ocean islands: An Australian perspective. Submitted to *Australian Journal of Entomology* (Appendix 3).

13.0 ACKNOWLEDGMENTS

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14.0 REFERENCES

Allsopp PG. 2001. Summary of effectiveness of tebufenozide for control of sugarcane stemborers. *BSES Publication* PR01004.

Allsopp PG, FitzGibbon F and De Barro PJ. 1999. Pest incursion management plan. BSES Publication PR98006.

Allsopp PG, Sallam MN, Graham GC & Scott K. 2001. Minimising the threat of lepidopteran borers to the Australian industry. *Proceedings of the International Society of Sugar Cane Technologists* 24: 389-391.

David H & Easwaramoorthy S. 1990. Biological control of *Chilo* spp. in sugar-cane. *Insect Science and its Application* 11: 733-748.

FitzGibbon F, Allsopp PG and De Barro PJ. 1998. Sugarcane exotic pests – Pest risk analysis database. *BSES Publication* CD98001.

FitzGibbon F, Allsopp PG and De Barro PJ. 1999a. Final report - SRDC project BSS175 Risk to the Australian sugar industry from exotic pests. *BSES Publication* SD98015.

FitzGibbon F, Allsopp PG and De Barro PJ. 1999b. Chomping, boring and sucking on our doorstep - the menace from the north. *Proceedings of the Australian Society of Sugar Cane Technologists* 21: 149-155.

Kuniata LS. 1999. Ecology and management of the sugarcane stem borer, *Sesamia grisescens* Warren (Lepidoptera: Noctuidae) in Papua new Guinea. PhD thesis, University of Queensland.

Overholt WA, Ngi-Song AJ, Omwega CO, Kimani SN, Mbapila J, Sallam MN & Ofomata V. 1997. A review of the introduction and establishment of *Cotesia flavipes* Cameron in East Africa for biological control of cereal stemborers. *Insect Science and its Application* 17: 79-88.

Polaszek A & Walker AK. 1991. The *Cotesia flavipes* species complex: Parasitoids of cereal stemborers in the tropics. *Redia* 74: 335-341.

Sallam MN. 2002. Summary of the effectiveness of lambda-cyhalothrin for control of sugarcane stemborers. *BSES Publication* PR02005.

Smith JW Jr, Wiedenmann RN & Overholt WA. 1993. Parasites of lepidopteran stemborers of tropical gramineous plants. ICIPE Science Press, Nairobi, Kenya.

APPENDIX 1 - DOSSIER FOR *CHILO SACCHARIPHAGUS*

***Chilo sacchariphagus sacchariphagus* (Bojer)**

Proceras sacchariphagus Bojer 1856: unnumbered; Tams 1942: 67; Kapur 1950: 412; Kalshoven 1950: 411.
Borer saccharellus Guenée 1862: unnumbered [syn. Tams 1942].
Chilo mauriciellus Walker 1863: 141. [syn. Tams 1942].
Chilo venosatus Walker 1863: 144 [syn. Bleszynski 1970].
Diatraea striatalis Snellen 1890: 98; 1891: 349 [syn. Hampson 1896b]
Diatraea mauriciella (Walker): Hampson 1896b: 953.
Diatraea venosata (Walker): Hampson 1896b: 954.
Diatraea mauriciella (Walker); Vinson 1941: 39; 1942: 39.
Proceras venosatus (Walker): Kapur 1950: 413; Bleszynski 1962a: 9.
Chilo sacchariphagus (Bojer): Bleszynski 1966: 494; 1969: 18; 1970: 182.

Types
sacchariphagus: Neotype male, Mauritius, in Museum National d'Histoire Naturelle, Paris.
striatalis: Lectotype male, Tegal, Java, Indonesia, in Museum van Natuurlijke Historie, Leiden.

Chilo sacchariphagus is often treated as three subspecies: *Chilo sacchariphagus sacchariphagus* (Bojer), *Chilo sacchariphagus stramineellus* (Caradja) and *Chilo sacchariphagus indicus* (Kapur). There are slight differences in the genitalia of the three subspecies, although the latter two are sometimes referred to simply as *C. sacchariphagus*. After examining several specimens, Bleszynski (1970) concluded that all populations belong either to one widely spread species, or to several phylogenetically very young species. Apparently geographical isolation of populations resulted in slight variations in the genitalia, however the differences can not be considered diagnostic.

Common names
Sugar-cane stalk borer; sugar cane internode borer, striped sugar cane borer, the spotted borer, spotted stem borer, internode borer, internodal borer, stalk borer, sugarcane spotted borer.

Distribution
Bangladesh, China, Comoros, India, Indonesia, Japan, Madagascar, Malaysia, Mauritius, Mozambique, Philippines, Reunion, Singapore, Sri Lanka, Taiwan, Thailand (Bleszynski 1970; Williams 1983; Facknath 1989; David & Easwaramoorthy 1990; Leslie 1994; Ganeshan & Rajabalee 1997; Suasa-ard 2000).

Chilo sacchariphagus is originally an Asian species. Populations in Madagascar, Mauritius and Reunion have probably been introduced by humans in the mid 1800s (Bleszynski 1970; Williams 1983). On mainland Africa, the pest was first recorded in Mozambique in 1991 in sugarcane (Way 1998).

Host plants
Sugarcane, wild *Saccharum* spp., maize, sorghum. *Chilo sacchariphagus* is mainly a pest of sugarcane. Reported to rarely attack maize and sorghum in Madagascar, Mauritius and Reunion (Betbeder-Matibet & Malinge 1968; Williams 1983)

Symptoms
Chilo sacchariphagus infests the plant from when it starts forming internodes until harvest time. Female moths lay their eggs in clusters on both surfaces of the leaves of sugarcane. Kalshoven (1981) reported that 7-30 eggs are laid in two parallel rows, mostly attached to the upper side of the leaf, and that an adult female lays about 80 eggs. Young larvae are very active and sometimes drop from the plant on silken threads, and can then be carried by wind. About 5-15 larvae penetrate one leaf sheath together. First instars feed mainly on leaves and leaf sheaths then later borrow inside the soft growing point of stalks resulting in dead hearts (David 1986). Larvae enter and eventually kill the spindle region near the growing point, leading to the sprouting of auxiliary buds and the formation of bunchy top. The migrating larva can attack the sprouts and cause more than one dead heart in the bunchy top. Early and late maturing varieties did not differ in their susceptibility, as they sustained equal losses in weight and recoverable sugar.

Economic Impact
Chilo sacchariphagus is a major pest of sugarcane in Indonesia, India, China and Taiwan, and in Madagascar, Reunion and Mauritius (where it was accidentally introduced probably from Java in 1850). *Chilo*

sacchariphagus also attacks sorghum and is considered to be one of its important pests in some parts of China (Chundurwar 1989). In Reunion, Goebel *et al.* (1999b) recorded losses up to 40 tons/ha of cane due to *C. sacchariphagus* infestation.

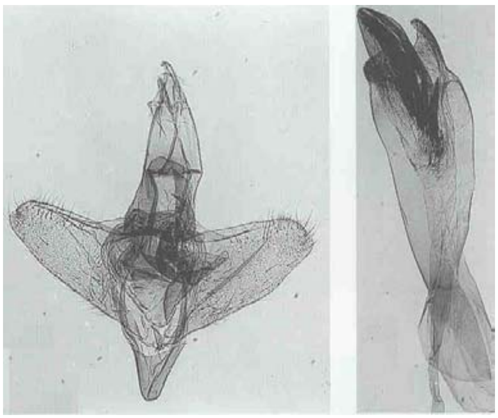
Kalaimani (1995) found that sprouting of side buds was promoted by the attack of the borer, in addition, smut incidence, bud size and internode borer incidence were found to be positively correlated. In Mauritius, it was found that the borer mainly reduced cane yield but had no effect on the sugar content (Anon. 1987). This was also confirmed later by (Rajabalee *et al.* 1990) who found that infestation was positively correlated with yield loss, especially in dry as compared to more humid regions, though juice purity was not affected. Similar observations are also reported from Reunion where no reduction of cane quality was recorded due to infestation (Anon. 1986).

In Taiwan, Cheng *et al.* (1997a) conducted biweekly surveys of damage in spring cane during 1984-94 and recorded 6.18% borer infestation, of which *Tetramoera schistaceana* constituted 46.1%, *C. infuscatellus* 33.8% and *C. sacchariphagus* 19.7%. *Sesamia inferens* and *Scirpophaga nivella* were also recorded. Damage by *C. sacchariphagus* appeared in the first half of June and increased during July and August. Cheng (1999) observed that the greatest damage was caused by *Tetramoera schistaceana*, which infested 8.20±1.25% internodes of the autumn cane and 4.42±0.55% internodes of the spring cane, while *C. sacchariphagus* was the next important one which caused 0.87±0.17% internode infestation in the autumn cane and 1.40±0.25% in spring cane.

In India, *C. sacchariphagus* was reported to cause 10.7% loss in cane yield (Agrawal 1964). Later damage reports from spring sorghum are up to 65% and 35% in summer sorghum (Chundurwar 1989).

Morphology
Adults
Bleszynski (1970) gives the following description of *C. s. sacchariphagus*: Ocellus reduced. Face rounded, not protruding forward beyond eye; corneous point and ventral ridge both absent. Labial palpus 3 (male) to four (female) times as long as diameter of eye. Fore wing: R_1 confluent with *Sc*; length 12.0-18.0 mm, maximum width 4.5-6.0 mm; apex acute; ground-colour dull light brown; veins and interneural spaces outlined with whitish beige; discal dot distinct, often double; terminal dots present; transverse lines absent; fringes slightly glossy, concolorous or lighter than the ground-colour. Hind wing dirty white to light brown in male, silky whitish in female.

Male genitalia (Figs 119-121): Valva slightly tapering to a rounded apex, which is very slightly concave; pars basalis absent; juxta-plate short, broad, deeply notched, arms tapered without teeth ; saccus V-shaped; aedeagus variable in width; ventral arm and basal process both absent; row of strong tapering cornuti present and subapical large patch of scobinations absent.

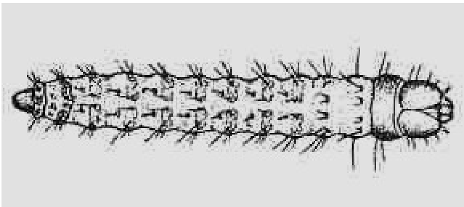


Male genitalia of *C. sacchariphagus* (after Polaszek 1998).

Female genitalia (Figs 125-126): Ostial pouch rather well demarcated from ductus bursae, heavily sclerotized longitudinal ribs; corpus bursae greatly elongate, longer than ductus bursae, with large area of scobinations.

Female genitalia of *C. sacchariphagus* (after Polaszek 1998).

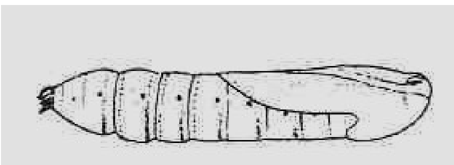
Larvae
Newly hatched larvae are marked by distinct red transversal stripes, while older larvae have four longitudinal stripes formed by the spots on the dorsal sides of the segments. Development takes about 2 months (Kalshoven 1981).



***C. sacchariphagus* larvae (after Kalshoven 1981).**

Differing forms of *C. sacchariphagus* larvae (after Polaszek 1998).

Pupae



***C. sacchariphagus* pupa (After Kalshoven 1989).**

Detection methods
Initial damage is easily identified by the way the unfolded leaf has been shaved and bored. White stripes and spots mottled with fine debris can be seen after leaves unfold, by the time which the larvae have already left the sheath and started boring inside the stem. Larvae then move upwards and may destroy the growing point causing dead heart. The pupa is found near the exit hole (Kalshoven 1981).

Biology and Ecology
In a survey of sugarcane borers in Gujarat, India, both *C. sacchariphagus* and *C. auricilius* were recorded only from June to December, while *Scirpophaga excerptalis* and *Emmalocera depressella* (*Polyocha depressella*)

were recorded to be active throughout the year, and *C. infuscatellus* was observed from January to June and November to December (Pandya *et al.* 1996). Chundurwar (1989) recorded that *C. sacchariphagus* has two generations per year in South East Asia, with peak ovipositions taking place in mid June and mid August for the first and second generations, respectively.

Easwaramoorthy & Nandagopal (1986) studied the population dynamics of *C. sacchariphagus* in Tamil Nadu, India, where they recorded high mortality of the early stages, which was attributed to parasitism by Hymenoptera, arthropod predation, desiccation, egg infertility and losses during dispersal of the first-instar larvae. Parasitism and granulosis virus infection were among the limiting factors in the later larval and pupal stages. A K-factor analysis showed that suspected arthropod predation, dispersal losses in the first larval instar, and losses due to migration and unknown causes in later larval instars were the key mortality factors.

In China, the pupation pattern of *C. sacchariphagus* was studied in maize fields, where 83.6% of the larvae pupated inside the leaf sheaths, while 16.4% pupated on maize ears (Wu 1995).

In Java, *C. sacchariphagus* does not occur above altitudes of 800 m (Kalshoven 1981).

Natural Enemies
Parasitoids
***Goniozus indicus* Ashmead (Hymenoptera: Bethylidae):** A gregarious larval endoparasitoid. Recorded on *C. sacchariphagus* in India (Box 1953; Butani 1958; Butani 1972). This species has a very wide range of stemborer species, and it is found in all of sub Saharan Africa, Mauritius, Madagascar, Bangladesh, India and Pakistan (Polaszek 1998).
***Agathis stigmatera* Cresson (*Alabagrus stigma* Brullé) (Hymenoptera: Braconidae):** Solitary larval endoparasitoid, final larval stage feeds externally. Introduced into Mauritius where it is reported to attack *C. sacchariphagus* (Ganeshan & Rajabalee 1997; Ganeshan 2000).
***Rhaconotus roslinensis* Lal (Hymenoptera: Braconidae):** Gregarious larval ectoparasitoid. Recorded from India on *C. sacchariphagus* (Butani 1958; Butani 1972). Hawkins & Smith (1986) reared this parasitoid successfully on *Diatraea saccharalis* and *Eoreuma loftini* as laboratory hosts.
***Bracon chinensis* (Hymenoptera: Braconidae):** Larval parasitoid. Introduced from Sri Lanka into Mauritius for the control of *C. sacchariphagus* in sugarcane (Greathead 1971).
***Cotesia flavipes* Cameron (Hymenoptera: Braconidae):** Gregarious larval endoparasitoid. Reported to give moderate-high mortality rates of *C. sacchariphagus* in Mauritius (Williams 1983; Facknath 1989; Ganeshan 2000), Madagascar (Betbeder-Matibet & Malinge 1968; Appert *et al.* 1969), Reunion (Greathead 1971), Taiwan (Box 1953; Cheng *et al.* 1987a), Indonesia (Kalshoven 1981; Sunaryo and Suryanto 1986; Mohyuddin 1987) and India (Easwaramoorthy & Nandagopal 1986; Easwaramoorthy *et al.* 1992). During 1990-93, Easwaramoorthy *et al.* (1998a) reported the mass production of a native strain of *C. flavipes* in sugarcane fields at Coimbatore, Tamil Nadu, India, where parasitoids were released at a density of 2,060-561,000 females/ha/month. However, results showed that the parasitoid failed to reduce the progress of borer infestation. In 1993, an Indonesian population of the parasitoid was also released in the field at 2,010-11,300 females/ha/month. Similarly, monthly parasitism rates showed no impact on *C. sacchariphagus* infestation. The authors mentioned that, in the laboratory, the parasitoid gave a male biased sex ratio. This could be a result of imperfect copulation between adults.
***Microbracon chinensis* (*Amyosoma chinensis*) (Hymenoptera: Braconidae):** Larval parasitoid. Recorded from Taiwan (Cheng *et al.* 1987).
***Rhaconotus* sp. (Hymenoptera: Braconidae):** Larval parasitoid. Recorded in Indonesia by Kalshoven (1981).
***Rhaconotus signipennis* Walker (Hymenoptera: Braconidae):** Larval parasitoid. Recorded from India (Butani 1972). Shenhmar & Varma (1988) described a rearing technique for this species on the sugarcane pest, *Acigona steniella* (*Bissetia steniella*) in the Punjab, India. Female parasitoids laid eggs in groups of 3-20 after paralysing the host larva. The preoviposition, incubation, larval and pupal periods of the braconid averaged 4, 2, 6.4 and 14.4 days, respectively. The life-cycle was completed in 22.8 ± 0.8 days. The lifespan of adult males averaged 11.6 days and that of females 11.9 days. The ratio of males to females was 1:10.
***Macrocentrus jacobsoni* Szépl. (Hymenoptera: Braconidae):** Larval endoparasitoid. Recorded attacking *C. sacchariphagus* in Taiwan (Box 1953).
***Campyloneurus erythrothorax* Szépl. (Hymenoptera: Braconidae):** Recorded attacking *C. sacchariphagus* in Indonesia (Kalshoven 1981).
***Allorhogas pyralophagus* (Hymenoptera: Braconidae):** Larval parasitoid. This species is native to Mexico. Reported to have been introduced into India for the control of *C. sacchariphagus*, though did not seem to establish (Varma *et al.* 1987; Easwaramoorthy *et al.* 1992). Also introduced into Mauritius and few recoveries were recorded (Facknath 1989). This species does not seem to be effective against stemborers.

Trichospilus diatraea **Chairman & Margabandhu (Hymenoptera: Chalcididae):** Pupal parasitoid. Recorded attacking *C. sacchariphagus* in India (Butani 1972), introduced from India into Mauritius (Facknath 1989).
Tetrastichus **sp. (near *atriclavus* Waterst.) (Hymenoptera: Eulophidae):** Recorded in Mauritius by Box (1953).
Tetrastichus atriclavus **Waterst (Hymenoptera: Eulophidae):** Pupal endoparasitoid. Recorded in Mauritius (Ganeshan & Rajabalee 1997).
Tetrastichus ayyari **Rohwer (Hymenoptera: Eulophidae):** Pupal parasitoid. Recorded in India on *C. sacchariphagus* (Butani 1958). This species was introduced from India into Ghana for the control of a complex of stemborer species during 1973-74 (Scheibelreiter 1980).
Trichospilus diatraeae **Cherian & Margabandhu (Hymenoptera: Eulophidae):** Pupal parasitoid. Recorded on *C. sacchariphagus* in India (Box 1953; Butani 1958) and Mauritius (Greathead 1971; Ganeshan 2000). This species was introduced from India into Senegal for the control of *C. zacconius* in 1972 (Vercambre 1977).
Meloboris sinicus **(Holmgren) (Hymenoptera: Ichneumonidae):** Larval parasitoid. In Taiwan, Cheng *et al.* (1999) reported this parasitoid attacking *C. sacchariphagus* and *C. infuscatellus* in spring cane in Taiwan.
Goryphus **sp. (Hymenoptera: Ichneumonidae):** Larval parasitoid. Recorded on *C. sacchariphagus* and other sugarcane borer species in India (Butani 1972).
Goryphus ornatipennis **Cameron: (Hymenoptera: Ichneumonidae):** Larval parasitoid. Recorded from Tamil Nadu, India, and exported to Taiwan (Butani 1972).
Amauromorpha schoenobii **Vier. (Hymenoptera: Ichneumonidae):** Recorded parasitising *C. sacchariphagus* in sugarcane fields in Indonesia (Box 1953).
Gambroides rufithorax **Uchida (Hymenoptera: Ichneumonidae):** Recorded parasitising *C. sacchariphagus* in sugarcane in Taiwan (Box 1953).
Enicospilus antankarus **Sauss. (Hymenoptera: Ichneumonidae):** Larval parasitoid, recorded in sugarcane in Mauritius (Box 1953).
Goryphus basilaris **Holmgren (Hymenoptera: Ichneumonidae):** Recorded as *Mesostenus longicornis* Ishida on *C. sacchariphagus* in India by Box (1953), later as *Goryphus basilaris* Holmgren on both *C. sacchariphagus* and *Tryporyza nivella* (see Butani 1972).
Xanthopimpla stemmator **Thunb (Hymenoptera: Ichneumonidae):** Pupal parasitoid. This species was successfully introduced from Sri Lanka into Mauritius to control *C. partellus*, where it is now well established and reported to parasitize *C. sacchariphagus* and *Sesamia calamistis* (Vinson 1942; Zwart 1998). From Mauritius, it was successfully introduced to Reunion and Mozambique against *C. sacchariphagus* in sugarcane (Caresche 1962; Conlong & Goebel 2002). This parasitoid has a fairly wide range of stemborers, its hosts include *Scirpophaga nivella*, *Sesamia inferens*, *C. suppressalis*, *C. zonellus*, *C. auricilia, Scirpophaga incertulas* and *Eldana saccharina* (Townes & Chiu 1970; Facknath 1989; Ganeshan 2000; Conlong & Goebel 2002). Also recorded attacking *C. sacchariphagus* in India (Butani 1972; Ganeshan & Rajabalee 1997), Indonesia (Kalshoven 1981) and Taiwan (Box 1953).
Xanthopimpla citrina **(Hlmgr.) (*Xanthopimpla luteola*) (Hymenoptera: Ichneumonidae):** Pupal parasitoid. This species is indigenous to Mauritius and the African continent (Zwart 1998). Recorded attacking *C. sacchariphagus* in Mauritius (Moutia & Courtois 1952; Facknath 1989).
Telenomus beneficiens **(Zehntner) (Hymenoptera: Scelionidae):** Egg parasitoid. Rajendran (1999) recorded *T. beneficiens* from September to March attacking up to 73.5% *C. sacchariphagus* eggs in the Cuddalore region of Tamil Nadu. Though it was not feasible to mass produce under laboratory conditions, *T. beneficiens* seems to cause a moderate degree of natural control of *C. sacchariphagus* in sugarcane fields in India (Easwaramoorthy *et al.* 1983; Rajendran & Gobalan 1995). Also recorded from Mauritius, Taiwan, Indonesia and China (Box 1953; Cheng *et al.* 1997b).
Telenomus dignoides **Nixon (Hymenoptera: Scelionidae):** Egg parasitoid. Recorded from India (Bin & Johnson 1982; Easwaramoorthy & Nandagopal 1986).
Telenomus globosus **n. sp. (Hymenoptera: Scelionidae):** Recorded attacking eggs of *C. sacchariphagus* in India (Bin & Johnson 1982; Easwaramoorthy & Nandagopal 1986).
Diatraeophaga striatalis **Tns. (Diptera: Tachinidae):** Larval parasitoid. Known as the silver-head tachinid fly. Recorded in Indonesia (Box 1953). Mass released at the Kadhipatan Sugar Estate in Indonesia and reported to have reduced borer losses from 20 % to 8% (Boedyono 1973).
Schistochilus aristatum **Aldr. (Diptera: Tachinidae):** Recorded in sugarcane in Java Box (1953).
Carcelia **sp. (Diptera: Tachinidae):** Larval parasitoid. The only record of this species on *C sacchariphagus* is from Indonesia (Kalshoven 1981). However, no other records of *Carcelia* sp. on *Chilo* spp. are available.
Sturmiopsis inferens **(Diptera: Tachinidae):** Larval parasitoid. Recorded on *C. sacchariphagus* in sugarcane in Indonesia (Mohyuddin 1987). This species was introduced from India to many parts of Africa for the control of a number of stemborer species (Kfir 1994; Overholt 1998).

Trichogramma chilonis **Ishii (*Trichogramma confusum*) (Hymenoptera: Trichogrammatidae):** Egg parasitoid. This species is mass released for the control of *C. sacchariphagus* in India (Rajendran & Hanifa 1998) and China (Liu *et al.* 1987). Selvaraj *et al.* (1994) reported a reduction in *C. sacchariphagus* damage to only 4% as a result of releasing 3 mL of eggs (18000 eggs/mL) in sugarcane fields of Coimbatore, Tamil Nadu, India. Also recorded from Taiwan (Cheng 1986) and Reunion (Goebel *et al.* 2000). In China, this parasitoid is produced on artificial host eggs. The parasitoid was released at 150000 parasitoids/ha for the control of *Chilo sacchariphagus* on sugarcane in 1984. Parasitism rate was similar with parasitoids from artificial and natural host eggs (Dai *et al.* 1988).
Trichogramma nubilale **(Hymenoptera: Trichogrammatidae):** Egg parasitoid. This species was introduced from the USA into Guangdong, China in 1983. Adult parasitoids were released in 800 mu (1 mu = 0.067 ha) of cane at a rate of 55 000/mu for the control of *Chilo sacchariphagus* and *Argyroploce schistaceana* (*Tetramoera schistaceana*). The parasitoid was reported to give better control than the native species *T. confusum* (*T. Chilonis*), and was more active especially during the summer (Liu *et al.* 1987).
Trichogramma **nr. *nana* (Zehnt.) (Hymenoptera: Trichogrammatidae):** This species is recorded parasitising eggs of *C. sacchariphagus* in sugar cane in Indonesia (Kalshoven 1981).
Trichogramma australicum **(Hymenoptera: Trichogrammatidae):** Recorded to be the most important egg parasitoid of *C. sacchariphagus* in cane fields in Mauritius (Ganeshan & Rajabalee 1997; Ganeshan 2000), also recorded in Madagascar and Taiwan (Box 1953).
Trichogramma evanescens minutum **(Hymenoptera: Trichogrammatidae):** Egg parasitoid, recorded parasitising *C. sacchariphagus* in sugar cane in India (Butani 1958).
Trichogramma nanum **Zhnt. (Hymenoptera: Trichogrammatidae):** Recorded parasitising eggs of *C. sacchariphagus* in sugarcane in Taiwan (Box 1953).

Predators
Easwaramoorthy and Nandagopal (1986) and Easwaramoorthy *et al.* (1996) provide this list of *C. sacchariphagus* predators recorded in sugarcane fields in India:
Coleoptera: Carabidae: *Hexagonia* sp? *insignis* (Bates).
Hymenoptera: Formicidae: *Camponotus rufogloucus* (Jerdon), *Camponotus compressus* (F.), *Monomorium aberrans* Forel, *Tetraponera refonigra* Jerdon, *Oecophylla amaragdina* F., *Solinopsis geminala* (F.), *Anoplolepis longipes* Jerdon, *Pheldiogeton* sp.
Araneae: Glubionidae: *Oedignatha* sp. **Lycosidae:** *Hippasa greenalliae; Oxyopes shweta; Paradosa* sp. **Oxyopidae:** *Oxyopes* sp. **Salticidae:** *Carrhotus viduus* Koch; *Plexippus paykulli* (Audouin). **Thomisidae**: *Runcinia* sp.
Pheidole megacephala **Fab**. (Hymenoptera: Formicidae): Recorded as an egg predator of *C. sacchariphagus* in Reunion and Mauritius (Williams 1978; Goebel *et al.* 1999a).

Pathogens
Hyphomycetes
***Hirsutella nodulosa*:** Fungal pathogen, recorded to give up to 11.4% infection of *C. sacchariphagus* in sugarcane fields of Coimbatore area of Tamil Nadu, India (Easwaramoorthy *et al.* 1998b).
***Metarhizium anisopliae*:** Fungal pathogen, recorded from Mauritius (Ganeshan 2000).
Paecilomyces **sp.** Fungal pathogen, recorded from Mauritius (Ganeshan 2000).

Mermithidae
Mermis **sp.** Entomopathogenic nematodes, recorded from Mauritius by Moutia and Courtois (1952).

Nosematidae
Nosema **sp.** Recorded from Reunion (Fournier & Etienne 1981).
***Nosema furnacalis*:** Recorded on *C. sacchariphagus* in China (Wen & Sun 1988).

Granulosis virus (GV): Reported from India to result in up to 31.5% mortality in eight canegrowing district of India (Easwaramoorthy & Nandagopal 1986; Easwaramoorthy & Jayaraj 1987).

Management
Chemical Control
In Zhanjiang, Guangdong, China, *Tetramoera schistaceana*, *C. infuscatellus* and *C. sacchariphagus* infested sugarcane heavily in the late 1990s, usually at the same time and mainly on internodes 3-15 of sugarcane plants. A mixture of trichlorfon and dimehypo applied to the whirl of sugarcane plants gave 72.1-83% control of the stemborer complex. 80% control of *C. sacchariphagus* was achieved using 0.25% demeton granules in sorghum in China (Anon. 1977).

In 1988, suSCon Fu Ming, a controlled-release granular formulation of 100 g/kg phorate, was registered for use on sugarcane in China. The target pests included *C. infuscatellus* and *C. sacchariphagus* as well as other soil pests. Trials showed that application at planting at 1.8-2.1 kg/ha controlled a range of borer and soil pests, and resulted in significant yield increases (May & Hamilton 1989).

In a field experiment in 1994-96 at Cuddalore, Tamil Nadu, India, Rajendran and Hanifa (1997) showed that the application of 2000 ppm of endosulfan or monocrotophos decreased the emergence of *Trichogramma chilonis* and did not reduce the incidence of *Chilo sacchariphagus* in sugarcane. In a field trial by Pandya (1997) in Gujarat, India, minimum infestation by *C. sacchariphagus* was achieved by the treatment of phorate 10 G at 1 kg a.i./ha.

Deltamethrin is used in Reunion (Goebel *et al.* 1999b).

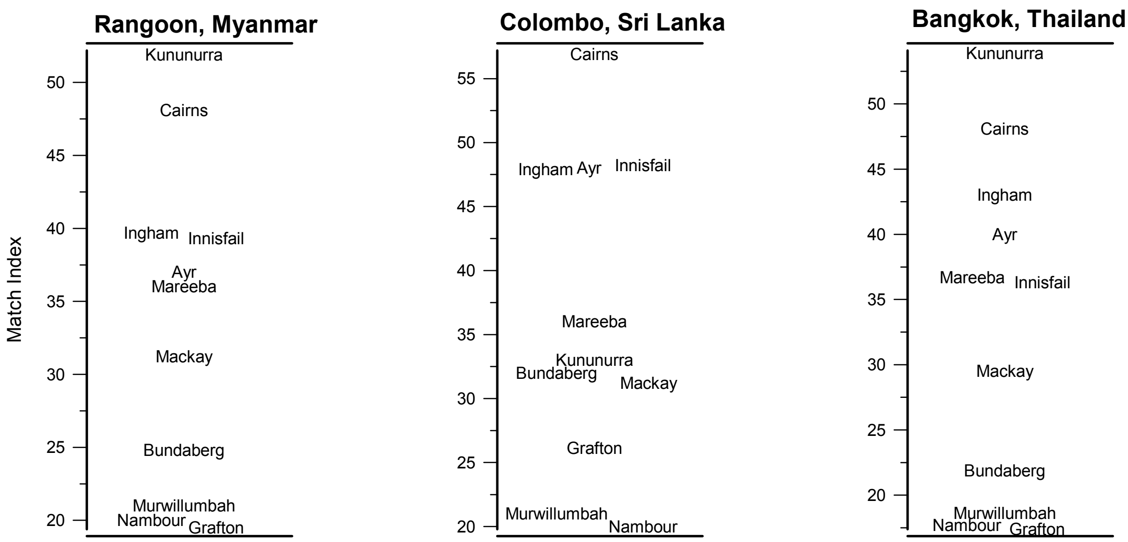
In Mozambique, where *C. sacchariphagus* where first reported in 1991, Way (1998) recommended that all cane moving between estates is fumigated with methyl bromide.

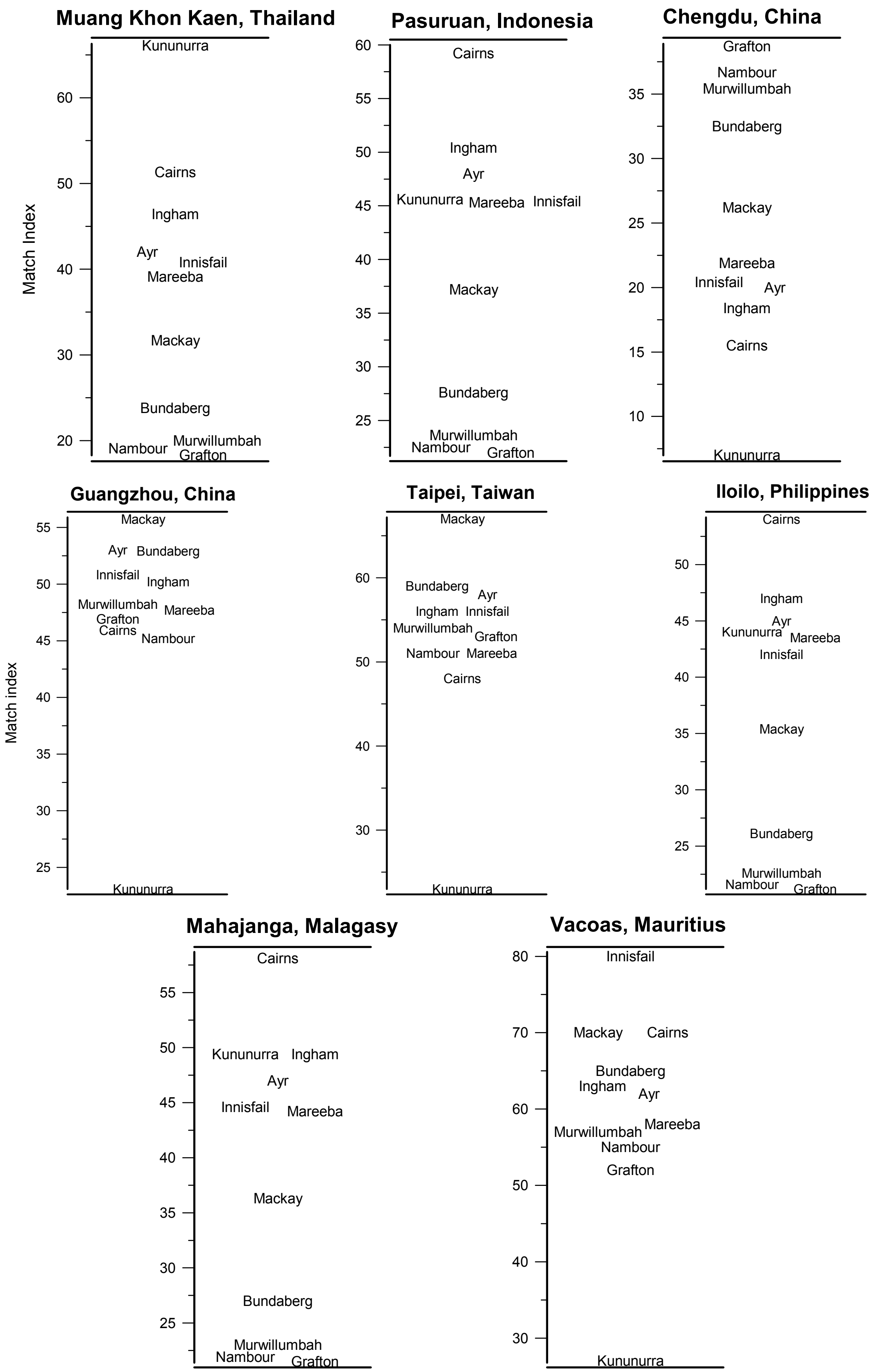
Thirumurugan *et al.* (2000) showed that though spraying of neem seed kernel extract at 5% on the 30th and 59th day after planting of sugarcane was effective against *C. infuscatellus*, but *C. sacchariphagus* infestation was not reduced.

Pheromones
Nesbitt *et al.* (1980) identified (Z)-13-octadecenyl acetate (Z13-18:Ac) and the corresponding alcohol (Z13-18:Alc) as the two main electrophysiologically active components in ovipositor washings from virgin female *C. sacchariphagus*. In field trials in Mauritius, individual components were not attractive to male moths, but traps baited with 7:1 mixtures of the components, which is the naturally occurring ratio, caught as many male moths as did virgin female baited traps. Microencapsulated formulations (ICI Agrochemical, UK) of Z13-18:Ac were similarly affective when applied as a spray at 10, 20, or 40 g/ha, or as spot applications at 1 or 2 m intervals, equivalent to an application rate of 20 g/ha. (see David *et al.* 1985; Beevor *et al.* 1990).

Means of Movement
The most likely means of entry of this species into Australia would be by the introduction of infested planting material. The chance of the introduction of moths or eggs on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk
Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Depends on biotype introduced (see Match Indexes for climates at selected locations and principal Australian areas below).




Muang Khon Kaen, Thailand
Match Index
Kununurra
Cairns
Ingham
Ayr
Innisfail
Mareeba
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton
Pasuruan, Indonesia
Cairns
Ingham
Ayr
Kununurra
Mareeba
Innisfail
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton
Chengdu, China
Grafton
Nambour
Murwillumbah
Bundaberg
Mackay
Mareeba
Innisfail
Ayr
Ingham
Cairns
Kununurra
Guangzhou, China
Match index
Mackay
Ayr
Bundaberg
Innisfail
Ingham
Murwillumbah
Mareeba
Grafton
Cairns
Nambour
Kununurra
Taipei, Taiwan
Mackay
Bundaberg
Ayr
Ingham
Innisfail
Murwillumbah
Grafton
Nambour
Mareeba
Cairns
Kununurra
Iloilo, Philippines
Cairns
Ingham
Ayr
Kununurra
Mareeba
Innisfail
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton
Mahajanga, Malagasy
Cairns
Kununurra
Ingham
Ayr
Innisfail
Mareeba
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton
Vacoas, Mauritius
Innisfail
Mackay
Cairns
Bundaberg
Ingham
Ayr
Murwillumbah
Mareeba
Nambour
Grafton
Kununurra

APPENDIX 2 – MANUSCRIPT ON BORER PHYLOGENY

Sugarcane moth borers (Lepidoptera: Noctuidae and Pyraloidea): phylogenetics constructed using COII and 16S mitochondrial partial gene sequences

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Abstract

Sugarcane moth borers are a diverse group of species in several genera, mainly within the Noctuidae and Pyraloidea. They cause economic loss in sugarcane and other crops through damage to stems and stalks by larval boring. Partial sequence data from two mitochondrial genes COII and 16S were used to construct a molecular phylogeny including 26 species from 10 genera and 6 tribes. The Noctuidae were found to be monophyletic, suggesting a robust taxonomy within this subfamily. However, the Pyraloidea were paraphyletic, with the noctuids splitting the Crambinae from the Galleriinae and Schoenobiinae. This supports the separation of the Pyralidae and Crambinae, but does not support the concept of the incorporation of the Schoenobiinae in the Crambidae. Of the three crambine genera examined, *Diatraea* was monophyletic, *Chilo* paraphyletic, and *Eoreuma* was basal to the other two genera. Within the Noctuidae, *Sesamia* and *Bathytricha* were monophyletic, with *Busseola* basal to *Bathytricha*. Many species in this study (both noctuids and pyraloids) had different biotypes within collection localities and across their distribution; the former were not phylogenetically informative. These data highlight the need for taxonomic revisions at all taxon levels and provides a basis for the development of DNA-based diagnostics for rapidly identifying many species at any developmental stage. This ability is vital, as the species are an incursion threat to Australia and have the potential to cause significant losses to the sugar industry.

Introduction

Insect species feeding on sugar cane are diverse, numerous, and characteristically of limited geographical distribution (Box, 1953; Pemberton & Williams, 1969; FitzGibbon et al., 1998). Few species are cosmopolitan; the majority are local species that have moved from feeding on grasses to feeding on introduced sugar cane (Strong et al., 1976). Of particular importance are the moth borers, a group of diverse Lepidoptera, primarily noctuids and pyraloids, which are key pests in most of the world's sugar industries. The group includes species that have a long evolutionary association with *Saccharum* spp. (e.g. *Sesamia grisescens* Warren), as well as species that have been spread by humans, (e.g. *Chilo saccariphagus* (Bojer)), and many species that have only recently adapted to feeding on cultivated sugar cane (e.g. Diatraea spp., *Eldana saccharina* (Walker), African *Sesamia* spp.).

Sugarcane stalks at any stage of growth are liable to attack from moth borers that are loosely classified into four types (Metcalfe, 1969) according to the part of the stalk that they attack: shoot borers; top borers; internode, stalk or stem borers; rootstock borers. However, a species is not necessarily restricted to one habit, e.g. *Chilo infuscatellus* Snellen is found as a shoot, top and internode borer; the distinction between types is largely based on the stage of development of the stalk and is purely arbitrary (Metcalfe, 1969). Shoot borers kill the shoots, with the first noticeable sign of damage being the characteristic 'dead heart' following damage to the base of the spindle leaves. Top borers attack the youngest part of the plant top, and usually destroy the growing point. Young stalks die; older stalks often die or produce side shoots and sucrose content is usually adversely affected. Internode borers tunnel in, and sometimes through, the internodes. The stalks lose weight and subsequent fungal infection induces rotting and death of the whole stalk. Juice quality can also be affected. Rootstock borers enter at or below ground level; young stalks show 'dead hearts', whilst older ones are weakened or killed.

Despite their dominance in most sugar industries, moth borers are not significant pests of Australian sugarcane (Allsopp et al. 2000), although species such as *Bathytricha truncata* (Walker) are minor pests. Genera such as *Chilo* Zincken, *Diatraea* Guilding, *Eldana* Walker, *Scirpophaga* Treitschke and *Sesamia* Guenée are either not present in Australia or are represented by species that do not feed on sugar cane (Nielsen et al., 1996). Many of the shoot, stem and top borers found in Southeast Asia and Papua New Guinea have been identified as threats to the Australian industry (FitzGibbon et al., 1999). For example, the Papua New Guinean noctuid *Sesamia grisescens* could easily establish in northern Queensland (Allsopp & Sallam, 2001) and cause damage similar to that in Papua New Guinea, where it reduced annual sugar production during the early 1990s by 5-18%, or reduced sugar production in the late 1980s by up to US$8.4 million annually (Kuniata & Sweet, 1994). The detrimental impact on the Australian sugar industry from such pests could see sugar production significantly reduced, given that there are no existing control measures (Allsopp et al., 2001).

Identification of a species is critical in framing the correct response to any incursion, forming the basis for appropriate control and eradication measures. The Australian sugar industry has determined that the accurate and rapid identification of borer larvae is a biosecurity priority (Allsopp *et al.*, 2001). Given that larvae of many species are impossible to separate morphologically, DNA-based methods could provide a useful technique. Phylogenetics is a tool frequently used for establishing inter- and intra-specific relationships between taxa and within populations. The mitochondrial large ribosomal subunit (16S) and protein-coding cytochrome oxidase II (COII) genes have been used extensively to infer phylogenetic relationships in insect families such as Drosophilidae (Simon *et al.*, 1994), Tephritidae (Smith *et al.*, 2003) and Lepidoptera (Sperling & Hickey, 1994), and could be useful and appropriate for phylogenetic reconstruction of the moth borers of sugarcane. Only one study has used this technique on sugarcane moth borers; King *et al.* (2002) successfully used COI-COII sequence data to show that different biotypes of the pyralid *Eldana saccharina* exist in Africa.

In this study, we use molecular phylogenetics to provide a hypothesis of relationships between sugarcane moth borers as the first stage in improving diagnostics. The study includes Australian endemic species and potential incursion threats.

Materials and methods

Sample sources and DNA extraction

Specimens were collected from Australia and sourced from overseas. Australian material was identified by MNS or PGA; overseas material was identified by sugarcane entomologists in the respective country. Material was stored in 100% ethanol. Twenty-six taxa from 10 genera were included (table 1). One species, *Cosmopterix* sp., is not a true 'moth borer', its larvae bore into the mid-ribs of sugarcane (Jarvis, 1927; Common, 1990); it was included as an outgroup, with *Opogona glycyphaga*, for the phylogenetic analysis. We usually included five individuals of each collection for analysis; where material was limited, fewer were used (table 1). DNA was extracted from hind proleg segments of individual larva or head and thorax of individual adults into a 96-well plate with the remaining insect tissue stored in 100% ethanol as laboratory voucher specimens. DNA extraction used a modified salting-out procedure of Miller *et al.* (1988) for use in 96-well plate format.

Cytochrome oxidase II amplification

Polymerase Chain Reaction (PCR) amplification of approximately 369 base pairs of the COII DNA fragment was carried out in 25µl total reaction volumes containing 4mM $MgCl_2$, 20mM Tris-HCl, 100mM KCl, 0.2mM of each dNTP (Biotech, Perth, Western Australia, Australia), 0.2µM of each primer mtD16 and mtD20 (Liu & Beckenbach, 1992; Simon *et al.*, 1994), 1U *Taq* polymerase (Qiagen, Clifton Hill, Victoria, Australia), and 20ng DNA. Thermal cycling was performed in a PC960 Thermal Cycler (Corbett Research, Mortlake, NSW, Australia) using the cycling conditions of 35 cycles at: 94°C for 30 seconds; 50°C for 60 seconds; 72°C for 60 seconds.

16S amplification

PCR amplification of approximately 378 base pairs of the 16S DNA fragment was carried out in 25µl total reaction volumes containing 2.0mM $MgCl_2$, 20mM Tris-HCl, and 100mM KCl, 0.2mM each dNTP (Biotech, Perth, Western Australia), 0.2µM each primer (16ScbF: 5'-AAGATTTTAATGATCGAACAG-3', 16ScbR: 5'-TGACTGTACAAAGGTAGCATA-3'), 1U *Taq* polymerase (Qiagen, Clifton Hill, Victoria, Australia) and 20 ng DNA. Thermal cycling was performed in a PC960 Thermal Cycler (Corbett Research, Mortlake, NSW, Australia) using the cycling conditions of 40 cycles at: 92°C for 45 seconds; 50°C for 60 seconds; 72°C for 90 seconds.

Visualisation, purification and sequencing

Amplified PCR products were checked on 1.5% Tris-borate-EDTA agarose gel to confirm amplification success, before PCR purification using MultiScreen-PCR plates (Millipore, North Ryde, NSW, Australia). Sequencing was performed in the forward and reverse directions in a 12µl total reaction volume containing 4µl of AB V3.0 Big Dye Terminator chemistry (Applied Biosystems, Melbourne, Australia), 3.2pmol of primer, and 50ng of PCR product in a PC960 Thermal Cycler (Corbett Research, Mortlake, NSW, Australia) using a cycling program of 94°C for 5 minutes followed by 30 cycles at: 96°C for 10 seconds; 50°C for 5 seconds; 60°C for 4 minutes. Sequences were purified using Montage SEQ_{96} Sequencing Reaction Cleanup Kits (Millipore, North

Ryde, NSW, Australia), and run on an AB 377 DNA sequencer (Applied Biosystems, Melbourne, Australia) at the Australia Genome Research Facility (University of Queensland, Australia). Sequence data for both the COII and 16S genes for all taxa are available at Genbank and accession numbers are given in Table 1.

Alignment and phylogenetic analyses

Sequences were aligned with BioEdit (Hall, 1999). Consensus sequences were derived from aligned forward and reverse complemented sequences of multiple individuals from taxa collected from specific locations (table 1). Refined alignments were completed manually to improve positional homology assessments, under the assumption that gaps are rare and to preserve local positional homology in adjacent positions. Gaps in aligned sequences were treated as missing data.

Phylogenetic analyses were performed using equal-weighted parsimony methods available in PAUP* (Swofford, 2002). The two mitochondrial genes sequenced are physically linked in the mitochondrial genome and were treated as one set of characters. Variation in characters between taxa was scored as polymorphic. Gaps positions were treated as a fifth base and missing sequence was coded as '?' and ambiguous characters coded as 'N'. Phylogenetic analysis of the data completed 1000 random stepwise additions searches, with tree bisection reconnection (TBR) branch swapping, MULPARS and branches having maximum lengths of zero were collapsed to yield polytomies. Strict Consensus of the most parsimonious trees (MPT) was computed by PAUP*. Bremer support (BS) (Bremmer 1994) values were calculated with 20 heuristic searches of the data and PAUP* (Swofford, 2002) with 100 random-addition heuristic searches topographically constrained to find the most parsimonious trees without the nodes present in the combined analysis. Bootstrap analysis was undertaken to establish additional support values for nodes within the combined analysis. Support for all nodes was estimated by bootstrapping, which was conducted using 1000 replicates with 100 random additions heuristic searches of the combined data set.

Results

Partial fragments of COII of 369 bp and 16S of 378 bp were sequenced. Genbank accession numbers are given in Table 1. Multiple haplotypes occurred within specimens of a species from a single geographic location, although none of these were phylogenetically informative. A total of three MPTs were computed for the combined data, consisting of 298 phylogenetically informative characters and each tree gave a length of 1337 steps. A consensus tree was computed with a Consistency Index (CI) of 0.4031 and a Retention Index (RI) 0.6853.

Cosmopterix sp. (Gelechioidea) and *Opogona glycyphaga* (Tineoidea) are outgroups for the pyraloids and noctuids used in this phylogeny (fig. 1). The noctuids are monophyletic, with each of the three genera forming a distinct clade. The pyraloids, however, are distinctly paraphyletic, splitting between the subfamilies Crambinae (*Chilo* and *Diatraea*) and the Schoenobiinae (*Scirpophaga*) and the Galleriinae *(Eldana*). Within the Crambinae, the genus *Diatraea* is monophyletic, but *Chilo* separates into two clades: *C. sacchariphagus* and *C. tumidicostalis*; *C. terrenellus*, *C. orichalcociliellus*, *C. infuscatellus*, *C. auricilius* and *C. partellus*. *Eoreuma loftini* is basal to the other crambines.

Genetic differences within species are also evident; phylogeographic separation is apparent between locations for a single species. *Scirpophaga excerptalis*, *Sesamia calamistis* and *Diatraea centrella* show clear differences between the geographic locations examined. Other species show significant splits along geographic lines: *Eldana saccharina* within Africa; *Bathytricha truncata* within Australia; separation of Indian and African collections of *Chilo partellus*; separation of Asian and Mauritius-Réunion collections of *Chilo sacchariphagus*; separation of Mexican-South American and USA-Caribbean collections of *Diatraea saccharalis*.

Discussion

Our analysis covered all of the major genera of sugarcane moth borers and many of the major species that are incursion threats to the Australian sugar industry. The analysis contained 26 species from 10 genera in six tribes. This study provides the first phylogenetic analysis of this diverse group. It indicates that some groups are paraphyletic at family, subfamily and generic levels; other groups are monophyletic and accord well with current taxonomies.

Cosmopterix sp. (Gelechioidea) and *Opogona glycyphaga* (Tineoidea) were defined as outgroups, consistent with their general placement within lepidopteran classifications (e.g. Common, 1990; Nielsen & Common, 1991; Scoble, 1995; Nielsen *et al.*, 1996; Holloway *et al.,* 2001) and with more rigorous analysis of lepidopteran phylogenies (Nielsen, 1989).

The noctuids, albeit only amphipyrines (sometimes amalgamated with the Acronictinae (Edwards, 1996), but probably not monophyletic (Scoble, 1995)), were monophyletic, suggesting a robust taxonomy within this subfamily. There is clear separation of *Busseola fusca* and *Bathytricha truncata* from *Sesamia* spp., suggesting that these three genera are valid. Tam and Bowden (1953) in their revision of African *Sesamia, Busseola* Thrau and related genera considered the first two distinct, although Holloway (1998) cast some doubt on the generic arrangement of the complex when he stated "The whole complex needs further review and might even be treated as *Sesamia sensu lato* until the characters within it can be more completely assessed. Some sections of it might be considered plesiomorphic and therefore possibly paraphyletic." However, he did maintain *Busseola* and *Sesamia* as valid genera, based on the shape of the costal process of the valve of the female genitalia.

Within *Sesamia,* our analysis clearly separates *cretica* (and an unidentified species from Iran) from *nonagrioides botanephaga* and *calamistis.* This is consistent with Tams and Bowden's (1953) separation of African *Sesamia* into two groups based on characters of the male antennae and of the male and female genitalia. Tams and Bowden (1953) speculated that the Oriental species of *Sesamia* were more closely related to the *cretica* group than to the *nonagrioides* group – our placement of the New Guinea species *grisescens*, the most easterly occurring *Sesamia,* closer to the *nonagrioides* group does not support this hypothesis.

The pyraloids are paraphyletic, with two major groups: the crambines (*Eoreuma loftini, Chilo* spp. and *Diatraea* spp.); and *Scirpophaga* (Schoenobiinae) and *Eldana* (Galleriinae). The separation of the pyralids from the crambines reflects one of the more contentious issues in lepidopteran phylogenetics. The more conservative view places all pyraloid subfamilies in the one family, the Pyralidae (e.g. Bleszynski, 1969, 1970; Fletcher & Nye, 1984; Holloway *et al.,* 1987, 2001; Common, 1990; Nielsen & Common, 1991; Zhang, 1994; Scoble, 1995; Schaffer *et al.,* 1996). However, a distinct division within this group was first noted by Börner (1925) and he split them into the Pyraliformes and Crambidiformes. This concept was refined further by Minet (1981, 1983, 1985), who placed the pyraloid subfamilies in either the Pyralidae or Crambidae depending on the presence or absence of a praecinctorium (a ventrally expanded medial flap anterior to the tympanal organs) and whether the tympanal organs are medially approximated or well separated. Systematic studies of pyraloid larvae by Hasenfuss (1960) provided further support for this division and this arrangement has met with some acceptance (e.g. Shaffer, 1990; Solis, 1992; Maes, 1995, 1998a,b; Kristensen, 1998). Both systems continue to be used, with "arguments for and against rest[ing] not over phylogenetic structure … but on merits of tradition and ranking" (Holloway *et al.* 2001). Our analysis partially supports the two-family concept; adult morphology places the Schoenobiinae with the Crambinae in the Crambidae. Our results suggest that the Crambidae *sensu lato* is paraphyletic.

Within the crambines, *Eoreuma* is clearly basal to *Chilo* and *Diatraea,* despite *loftini* being originally described in *Chilo*. According to Bleszynski (1969), *Diatraea* and *Chilo* form a compact monophyletic group, and are kept as distinct genera mainly for practical purposes. Our sequence data suggest that *Diatraea* is monophyletic, and that *Chilo* is paraphyletic, separating into two distinct clades. In our analysis, *Diatraea* resolves into two main groups: *centrella-crambidoides-grandiosella* and *busckella-rosa-saccharalis.* This differs from the implied phylogeny in Bleszynski's (1969) key, which groups the closely related *busckella-rosa* pair with *grandiosella,* and groups the closely related *crambidoides-saccharalis* pair with *centrella*. These two groups are differentiated on the patterns of dark spots on the wings, a character state that may not accurately reflect phylogeny.

Chilo was last revised by Bleszynski (1970), whose key separated *partellus* and *tumidicostalis* from the other species we examined on the basis of wing venation and *infuscatellus-sacchariphagus-terrenellus* from *auricilius-orichalcociliellus* on the basis of whether the forewings had metallic scales or not. Our arrangement is not consistent with this; we see two strong groups: *auricilius, infuscatellus, orichalcociliellus, partellus* and *terrenellus*; *sacchariphagus* and *tumidicostalis*. Indeed, the variation that we see, and the closer relationship of the second group with *Diatraea* than with the first suggest that the two groups should be in separate genera. There are available names for groups of *Chilo* (Bleszynski, 1970), other than for the group containing the type species *phragmitella* Hübner – *Diphryx* Grote (type species *prolatella* Grote = *plejadellus* Zincken), *Proceras* Bojer (*sacchariphagus*), *Nephalia* (*crypsimetalla* Turner), *Hypiesta* (*argyrogramma* Hampson), *Silveria* Dyar *(hexhex* Dyer = *chiriquitensis* (Zeller)) and *Chilotraea* Kapur (*infuscatellus* Snellen). Obviously, only a thorough revision of the genus and consideration of related genera will resolve the situation.

We found minor variation among specimens of most species from one collection locality. However, this variation was not phylogenetically informative. In specimens collected at different localities, we found considerable variation that was phylogenetically informative. In species represented by only two collections (*Scirpophaga excerptalis, Sesamia calamistis, Chilo infuscatellus* and *Diatraea centrella*), that variation was enough to show the presence of distinct biotypes. *Bathytricha truncata* shows differentiation in its Australian distribution with distinct haplotypes in Bundaberg, Ayr and Mackay. Variation in *Chilo partellus* is evident, with phylogenetic differentiation of Kenyan, Zimbabwean, South African and Indian collections. Further detailed investigation of these differentiations may reveal the presence of geographic isolation by distance, which may have an impact on potential biocontrol and eradication programmes.

Eldana saccharina shows phylogenetic differentiation between the Kenyan, Zimbabwean and South African collections. This species is almost certainly composed of different biotypes, with large phenotypical variation (Maes, 1998b), ecological differences (Conlong, 2001) and genetic differences among populations

(King *et al.,* 2002). Phylogenetic similarities between these collection localities may be the result of host dispersal by humans.

In *Chilo sacchariphagus*, the two Asian populations are closely related, as are the populations from Mauritius and Réunion – the latter pair probably come from the same stock, being introduced from Asia by humans in the mid 1800s (Bleszynski, 1970; Williams, 1983). However, the closer relationship of the Mauritius-Réunion collections with *C. tumidicostalis* from Thailand than with the Indian-Thailand collections of *C. sacchariphagus* suggests that the species is polyphyletic. *Chilo sacchariphagus* is sometimes treated as three subspecies: *Chilo s. sacchariphagus*, *Chilo s. stramineellus* (Caradja) and *Chilo s. indicus* (Kapur). There are slight differences in the genitalia of the three subspecies, although the latter two are sometimes referred to simply as *C. sacchariphagus*. After examining several specimens, Bleszynski (1970) concluded that all populations belong either to one widely spread species, or to several phylogenetically very young species. He thought that geographical isolation of populations has resulted in slight variations in the genitalia, but that the differences can not be considered diagnostic. Further genetic studies of the complex may resolve this issue.

In *Diatraea saccharalis,* the six populations tested resolve into two groups: Mexico and South America, and the Caribbean and southern USA. The differences could reflect two dispersals (presumably human-assisted), one to the north and east and one to the south, from an original evolution on grasses, perhaps the wild ancestor of maize, in southern Mexico. Our study indicates that further investigation of this potential relationship may be warranted.

In this study, we have shown that molecular phylogenetics provides alternate hypotheses of relationships between sugarcane moth borers and validates some current hypotheses. Currently recognised genera and species are undoubtedly polyphyletic and there is strong evidence that the moth borers in the Pyraloidea need to be placed in at least two families. Future studies should concentrate on resolving these issues using a wider group of species. Our findings also impact on the potential development of DNA-based diagnostics – any system needs to be robust enough to account for the variation that we have seen but still be workable and produce results useful in managing incursions.

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References

Allsopp, P.G. & Sallam, M.N. (2001) Sesamia *incursion management plan.* PR01002. Brisbane, Bureau of Sugar Experiment Stations.

Allsopp, P.G., Sallam, M.N., Graham, G.C. & Scott, K. (2001) Minimising the threat of lepidopteran borers to the Australian industry. *Proceedings of the International Society of Sugar Cane Technologists* **24**, 389-391.

Allsopp, P.G., Samson, P.R. & Chandler, K.J. (2000) Pest management. pp. 291-337 *in* Hogarth, D.M. & Allsopp, P.G. (*Eds*) *Manual of canegrowing.* Brisbane, Bureau of Sugar Experiment Stations.

Bleszynski, S. (1969) The taxonomy of crambine moth borers of sugar cane. pp. 11-15 *in* Williams, J.R., Metcalfe, J.R., Mungomery, R.W. & Mathes, R. *(Eds) Pests of sugar cane*. Amsterdam, Elsevier.

Bleszynski, S. (1970) A revision of the world species of *Chilo* Zincken (Lepidoptera: Pyralidae). *Bulletin of the British Museum (Natural History) Entomology,* **25**, 101-195.

Börner, C. (1925) Lepidoptera, Schmetterlinge. pp. 358-387 *in* Brohner, P. (*Ed.*) *Fauna aus Deutschland,* 3, verbesserte Auflage. Leipzig, Quelle and Meyer.

Box, H.E. (1953) *List of sugar cane insects.* London, Commonwealth Institute of Entomology.

Bremmer, K. (1994) Branch support and tree stability. *Cladistics* **10**, 295-304.

Common, I.F.B. (1990) *Moths of Australia.* Collingwood, CSIRO.

Conlong, D.E. (2001) Biological control of indigenous African stemborers. What do we know? *Insect Science and its Application* **21**, 1-8.

Edwards, E.D. (1996) Noctuidae. pp. 291-333 *in* Nielsen, E.S., Edwards, E.D. & Ransi, T.V. (*Eds*) *Checklist of the Lepidoptera of Australia.* Monograph on Australian Lepidoptera, Volume 4. Collingwood, CSIRO.

FitzGibbon, F., **Allsopp, P.G. & De Barro, P.J.** (1998) *Sugarcane exotic pests – pest risk analysis database.* CD98001. Brisbane, Bureau of Sugar Experiment Stations.

FitzGibbon, F., **Allsopp, P.G. & De Barro, P.J.** (1999) Chomping, boring and sucking on our doorstep – the menace from the north. *Proceedings of the Australian Society of Sugar Cane Technologists* **21**, 149-155.

Fletcher, D.S. & Nye, I.W.B. (1984) *The generic names of the moths of the world*. Volume 5, Pyraloidea.

London, British Museum (Natural History).

Hall, T.A. (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* **41**, 95-98.

Hasenfuss, I. (1960) Die Larvalsystematik der Zünsler (Pyralidae) aus dem Zoologischen Intstitut der Universität Erlangen. *Abhandlungen Larvalsystematik* **5**, 1-263.

Holloway, J.D. (1998) Noctuidae. pp. 79-86 *in* Polaszek, A. (*Ed.*) *African cereal stem borers: economic importance, taxonomy, natural enemies and control.* Wallingford, CAB International.

Holloway, J.D., Bradley, J.D. & Carter, D.J. (1987) *CIE guide to insects of importance to man. 1 Lepidoptera.* London, CAB International Institute of Entomology.

Holloway, J.D., Kibby, G. & Peggie, D. (2001) *The families of Malesian moths and butterflies*. Fauna Melesiana Handbook 3. Leiden, Brill.

Jarvis, E. (1927) Notes on insects damaging sugar cane in Queensland. Second edition. Revised. *Bulletin, Division of Entomology, Bureau of Sugar Experiment Stations, Queensland* **3**, 1-94.

King, H., Conlong, D.E. & Mitchell, A. (2002) Genetic differentiation in *Eldana saccharina* (Lepidoptera: Pyralidae): evidence from the mitochondrial cytochrome oxidase I and II genes. *Proceedings of the South African Sugar Technologists Association* **76**, 321-328.

Kristensen, N.P. (1998) *Lepidoptera, moths and butterflies. Volume 1: Evolution, systematics, and biogeography.* Handbook of zoology, Volume IV: Arthropod: Insecta, Part 35. Berlin, Walter de Gruyter.

Kuniata, L.S. & Sweet, P.M. (1994) Management of *Sesamia grisescens* Walker (Lep.: Noctuidae), a sugar-cane borer in Papua New Guinea. *Crop Protection* **13,** 488-493.

Liu, H. & Beckenbach, A.T. (1992) Evolution of the mitochondrial cytochrome oxidase II gene among ten orders of insects. *Molecular Phylogenetics & Evolution* **1,** 41-52.

Maes, K.V.N. (1995) A comparative morphological study of the adult Crambidae (Lepidoptera: Pyraloidea). *Bulletin et Annales de la Société Royale Belge d'Entomologique* **131**, 265-434.

Maes, K.V.N. (1998a) Lepidoptera: introduction. pp. 75-78 *in* Polaszek, A. (*Ed.*) *African cereal stem borers: economic importance, taxonomy, natural enemies and control.* Wallingford, CAB International.

Maes, K.V.N. (1998b) Pyraloidea: Crambidae, Pyralidae. pp. 87-98 *in* Polaszek, A. (*Ed.*) *African cereal stem borers: economic importance, taxonomy, natural enemies and control.* Wallingford, CAB International.

Metcalfe, J.R. (1969) The estimation of loss caused by sugar cane moth borers. pp. 61-79 *in* Williams, J.R., Metcalfe, J.R., Mungomery, R.W. & Mathes, R. *(Eds) Pests of sugar cane*. Amsterdam, Elsevier.

Miller, S.A., Dykes, D.D. & Polesky, H.F. (1988) A simple salting out procedure for extracting DNA from human nucleated cells. *Nucleic Acids Research* **16**, 1215.

Minet, J. (1981) Les Pyraloidea et leurs principales divisions systématiques. *Bulletin de la Société Entomologique de France* **86**, 262-280.

Minet, J. (1983) Étude morphologique et phylogénétique des organs tympaniques des Pyraloidea. 1 – Généralités et homologies. (Lep. Glossata). *Annales de la Société Entomologique de France (n.s.)* **19**, 175-207.

Minet, J. (1985) Étude morphologique et phylogénétique des organs tympaniques des Pyraloidea. 2 – Pyralidae; Crambidae première partie. (Lepidoptera Glossata). *Annales de la Société Entomologique de France (n.s.)* **21**, 69-86.

Nielsen, E.S. (1989) Phylogeny of major lepidopteran groups. pp. 281-294 *in* Fernholm, B., Bremer, K. & Jörnvall, H. (*Eds*) *The hierarchy of life. Molecules and morphology in phylogenetic analysis*. Amsterdam, Elsevier.

Nielsen, E.S. & Common, I.F.B. (1991) Lepidoptera (Moths and butterflies). pp. 817-917 *in* Naumann, I.D. (*Ed.*) *The insects of Australia,* Volume 2 (2nd edition). Carlton, Melbourne University Press.

Nielsen, E.S., Edwards, E.D. & Ransi, T.V. (1996) *Checklist of the Lepidoptera of Australia.* Monograph on Australian Lepidoptera, Volume 4. Collingwood, CSIRO.

Pemberton, C.E. & Williams, J.R. (1969) Distribution, origins and spread of sugar cane insect pests. pp. 1-9 *in* Williams, J.R., Metcalfe, J.R., Mungomery, R.W. & Mathes, R. *(Eds) Pests of sugar cane*. Amsterdam, Elsevier.

Scoble, M.J. (1995) *The Lepidoptera. Form, function and diversity.* Oxford, Natural History Museum and Oxford University Press.

Shaffer, J.C. (1990) Pyralidae of Aldabara Atoll. 1. Peoriinae. *Tropical Lepidoptera* **1**, 21-24.

Shaffer, M., Nielsen, E.S. & Horak, M. (1996) Pyralidae. pp. 164-199 *in* Nielsen, E.S., Edwards, E.D. & Ransi, T.V. (*Eds*) *Checklist of the Lepidoptera of Australia.* Monograph on Australian Lepidoptera, Volume 4. Collingwood, CSIRO.

Simon, C., Frati, F., Beckenbach, A., Crespi, B., Liu, H. & Flook, P. (1994) Evolution, weighting, and phylogenetic utility of mitochondrial gene sequences and a compilation of conserved polymerase chain reaction primers. *Annals of the Entomological Society of America* **87**, 651-701.

Smith, P.T., Kambhampati, S. & Armstrong, K.A. (2003) Phylogenetic relationships among *Bactrocera* species (Diptera: Tephritidae) inferred from mitochondrial DNA sequences. Molecular Phylogenetics and Evolution **26** 8-17.

Solis, M.A. (1992) A phylogenetic analysis and reclassification of the genera of the *Pococera* complex (Lepidoptera: Pyralidae: Epipaschiinae). *Journal of the New York Entomological Society* **101**, 1-83.

Sperling, F.A.H. & Hickey, D.A. (1994) Mitochondrial DNA Sequence Variation in the Spruce Budworm Species Complex (*Choristoneura*: Lepidoptera). *Molecular Biology and Evolution* **11**, 656-665.

Strong, D.R., McCoy, E.D. & Rey, J.R. (1976) Time and the number of herbivore species. *Ecology* **58**, 167-175.

Swofford, D.L. (2002) *PAUP*. Phylogenetic analysis using parsimony (* and other methods), version 4.0.* Sunderland, Sinauer Associates.

Tams, W.H.T. & Bowden, J. (1953) A revision of the African species of *Sesamia* Guenée and related genera (Agrotidae - Lepidoptera). *Bulletin of Entomological Research* **43**, 645-678.

Williams, J.R. (1983) The sugar cane stem borer (*Chilo sacchariphagus*) in Mauritius. *Revue Agricole et Sucrière de l'Île Maurice* **62**, 5-23.

Zhang, B-C. (1994) *Index of economically important Lepidoptera*. Wallingford, CAB International.

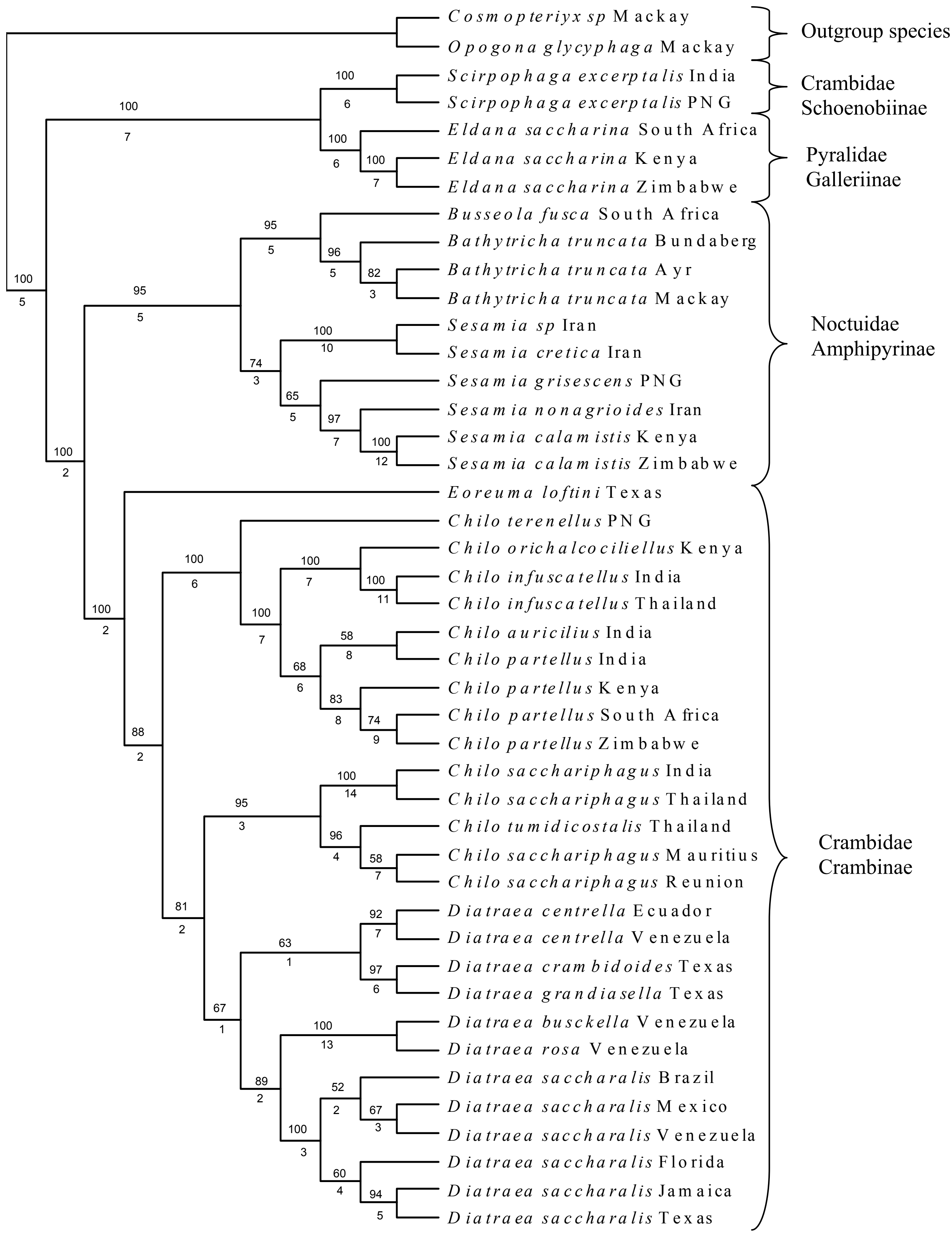
CAPTION TO FIGURE

Figure 1. Sugarcane moth stem and stalk borer phylogeny with Bootstrap values above and Bremer support values below the nodes. The outgroup species are *Cosmopterix* sp. (Gelechioidea: Cosompterigidae) and *Opogona glycyphaga* (Tineoidea: Hieroxestinae). Collection localities are indicated after the species name.

Table 1. Collection locations, numbers of specimens, and Genbank accession numbers for taxa included in the phylogenetic analysis.

Family and subfamily	**Species**	**Location**	**Stage**	**Number of individuals**	**GenBank accessions 16S**	**GenBank accessions COII**
Cosmopterigidae, Cosmopteriginae	*Cosmopterix* sp.	Mackay, Australia	Larva	2	AY320442	AY320489
Crambidae, Crambinae	*Chilo auricilius* Dudgeon	India	Larva	3	AY320428	AY320475
	C. infuscatellus Snellen	India	Larva	3	AY320429	AY320476
		Thailand	Larva	5	AY320430	AY320477
	C. orichalcociliellus (Strand)	Kenya	Larva	5	AY320431	AY320478
	C. partellus (Swinhoe)	India	Larva	3	AY320432	AY320479
		Kenya	Larva	5	AY320433	AY320480
		Zimbabwe	Larva	3	AY320435	AY320482
		South Africa	Adult	5	AY320434	AY320481
	C. sacchariphagus (Bojer)	Thailand	Larva	4	AY320439	AY320486
		Mauritius	Larva	5	AY320437	AY320484
		Réunion	Larva/adult	5	AY320438	AY320485
	C. sacchariphagus indicus (Kapur)	India	Larva	3	AY320436	AY320483
	C. terrenellus Pagenstecher	Papua New Guinea	Larva	5	AY320440	AY320487
	C. tumidicostalis (Hampson)	Thailand	Adult	5	AY320441	AY320488
	Diatraea busckella Dyar and Heinrich	Venezuela	Larva	5	AY320443	AY320490
	D. centrella (Motschulsky)	El Rodeo, Venezuela	Larva	3	AY320445	AY320492
		Ecuador	Adult	4	AY320444	AY320491
	D. crambidoides (Grote)	Texas, USA	Adult	5	AY320446	AY320493
	D. grandiosella Dyar	Texas, USA	Larva	5	AY320447	AY320494
	D. rosa Heinrich	Yaritagua, Venezuela	Larva	3	AY320448	AY320495
	D. saccharalis (Fabricius)	Florida, USA	Adult	5	AY320450	AY320497
		Texas, USA	Adult	5	AY320453	AY320500
		Mexico	Larva/adult	5	AY320452	AY320499
		Jamaica	Adult	5	AY320451	AY320498
		Chivacoa, Venezuela	Larva	3	AY320454	AY320501

		Brazil	Adult	5	AY320449	AY320496
	Eoreuma loftini (Dyar)	Texas, USA	Larva/adult	5	AY320458	AY320505
Crambidae, Schoenobiinae	*Scirpophaga excerptalis* (Walker)	India	Larva	3	AY320460	AY320507
		Papua New Guinea	Larva	5	AY320461	AY320508
Noctuidae, Amphipyrinae	*Bathytricha truncata* (Walker)	Ayr, Australia	Larva	4	AY320424	AY320471
		Mackay, Australia	Larva	5	AY320426	AY320473
		Bundaberg, Australia	Larva	5	AY320425	AY320472
	Busseola fusca Fuller	South Africa	Larva	5	AY320427	AY320474
	Sesamia sp.	Ahvaz, Iran	Larva	3	AY320462	AY320509
	S. calamistis Hampson	Kenya	Larva	5	AY320463	AY320510
		Zimbabwe	Larva	5	AY320464	AY320511
	S. cretica Lederer	Ahvaz, Iran	Adult	3	AY320465	AY320512
	S. grisescens Warren	Papua New Guinea	Larva	5	AY320466	AY320513
	S. nonagrioides botanephaga Tams and Bowden	Ahvaz, Iran	Adult	3	AY320467	AY320514
Pyralidae, Galleriinae	*Eldana saccharina* (Walker)	Kenya	Larva	5	AY320455	AY320502
		Zimbabwe	Larva	5	AY320457	AY320504
		South Africa	Larva/adult	5	AY320456	AY320503
Tineidae, Hieroxestinae	*Opogona glycyphaga* Meyrick	Mackay, Australia	Larva	2	AY320459	AY320506


Cosmopteriyx sp Mackay
Opogona glycyphaga Mackay
Scirpophaga excerptalis India
Scirpophaga excerptalis PNG
Eldana saccharina South Africa
Eldana saccharina Kenya
Eldana saccharina Zimbabwe
Busseola fusca South Africa
Bathytricha truncata Bundaberg
Bathytricha truncata Ayr
Bathytricha truncata Mackay
Sesamia sp Iran
Sesamia cretica Iran
Sesamia grisescens PNG
Sesamia nonagrioides Iran
Sesamia calamistis Kenya
Sesamia calamistis Zimbabwe
Eoreuma loftini Texas
Chilo terenellus PNG
Chilo orichalcociliellus Kenya
Chilo infuscatellus India
Chilo infuscatellus Thailand
Chilo auricilius India
Chilo partellus India
Chilo partellus Kenya
Chilo partellus South Africa
Chilo partellus Zimbabwe
Chilo sacchariphagus India
Chilo sacchariphagus Thailand
Chilo tumidicostalis Thailand
Chilo sacchariphagus Mauritius
Chilo sacchariphagus Reunion
Diatraea centrella Ecuador
Diatraea centrella Venezuela
Diatraea crambidoides Texas
Diatraea grandiasella Texas
Diatraea busckella Venezuela
Diatraea rosa Venezuela
Diatraea saccharalis Brazil
Diatraea saccharalis Mexico
Diatraea saccharalis Venezuela
Diatraea saccharalis Florida
Diatraea saccharalis Jamaica
Diatraea saccharalis Texas
Outgroup species
Crambidae
Schoenobiinae
Pyralidae
Galleriinae
Noctuidae
Amphipyrinae
Crambidae
Crambinae

APPENDIX 3 – MANUSCRIPT ON NATURAL ENEMIES OF BORERS

A review of sugarcane stemborers and their natural enemies in Asia and Indian Ocean islands: An Australian perspective

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Running title: Sugarcane borers, an Australian perspective (Sallam MN).

Abstract
This paper provides a review on stemborer pests of gramineous crops in Asia and Indian Ocean Islands which may have the potential to invade Australia. Information on the geographical distribution, host plants and potential of invading Australia is provided for 24 stemborer species with special reference to those mainly attacking sugarcane. A literature review of all natural enemies of 18 key pest species is provided. About 800 records of parasitoids, predators and pathogens of these pests are listed, with information on the host stage they attack, host plant or crop where they were recorded and country of record. The list includes all records of indigenous natural enemies, as well as introduced ones that are recorded to have been established in the country of introduction. This information will facilitate quick decision making in case of introduction of one of these pests into Australia. A knowledge of possible biological control options is essential to determine which natural enemies are to be considered for introduction following an incursion. Efforts from biological control programs attempted overseas are highlighted to provide insight into the complexity of this approach, and to assist in arriving at a correct decision within an acceptable length of time.
Key words: Stemborers, sugarcane, Australia, natural enemies, *Chilo*, *Sesamia*, *Scirpophaga*, *Maliarpha*, *Acigona*, *Argyroploce*, *Cotesia*

Introduction

Lepidopterous stemborers are major pests of gramineous plants in most countries of the world (Harris 1990; Polaszek 1998; Kuniata 1999). Most stemborers are able to attack a range of plant hosts such as maize, sorghum, millet, rice and sugarcane. Stemborers also attack a vast range of wild grasses, which were essentially their natural hosts before the development of subsistence farming and large scale monoculture. In Australia, major stemborer species are not known to be present, however, serious stemborer pest species exist in the neighbouring countries north of Australia and on the Indian Ocean islands. Species belonging to the genera *Chilo*, *Sesamia*, *Scirpophaga*, *Maliarpha*, *Acigona* (*Bissetia*) and *Argyroploce* (*Tetramoera*) are frequently distributed in countries to the north of Australia. A number of these borers chiefly attack sugarcane, while others are mainly pests of other cereal crops such as maize, sorghum or rice, but can exploit sugarcane for their development. The incursion of any of these pests into Australia would result in severe consequences to the Australian sugar industry, especially when some of these pests reach the immediate north of the Australian continent. For example, one notorious pest of cane, *Sesamia grisescens* Warren (Lepidoptera: Noctuidae), occurs in Papua New Guinea, where infestation in the early nineties resulted in sugar production losses of up to 8.4 million US dollars (Kuniata & Sweet 1994).

Potential for incursion differs from one species to the other, usually the closer and more serious and widely distributed the pest the higher the possibility of invasion. Measurements of preparedness for possible borer incursion into Australia have been formulated (Allsopp *et al.* 2000), which detail the steps to be taken once a pest is detected. One aspect of the preparedness for incursion is to pave the way for importation of a host-specific and efficient natural enemy of the pest in focus. It is important therefore to first identify major borer species in the neighbouring countries, investigate their distribution and economic importance, and identify their commonly recorded natural enemies to be able to recognize the most suitable candidate for importation into Australia in case of incursion.

The role of natural enemies in the control of pest populations is an area that received extensive amount of research during the past century in the hope of minimizing the use of pesticides in pest control. There is a wealth of information on successful as well as failed classical biological control programs around the world, whereby a natural enemy is collected from a country of origin and released in another country for the management of a pest problem. Several successful attempts of classical biological control of gramineous stemborers are well documented, such as the notable success of the establishment of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in East Africa and Indian Ocean islands on a range of stemborer species (Rajabalee & Governdasamy 1988; Polaszek & Walker 1991; Overholt *et al.* 1997). On the other hand, it's important to realize that not all attempts of classical biological control of stemborers have resulted in the establishment of the introduced natural enemies or in any significant degree of control. For example, during the period from 1966 to 1973, many attempts were made to introduce the tachinid *Lydella striatalis* (*Diatraeophaga striatalis*) from Java into the Indian Ocean islands of Mauritius, Madagascar, Reunion and the Comoros for the control of *Chilo sacchariphagus* in sugarcane. The parasitoids however failed to establish (Brenière *et al*. 1966; Appert (1973; Brenière *et al*. 1985; Polaszek 1998). In 1968, *Pediobius furvus* (Hymenoptera: Eulophidae) was introduced from Africa and released in Madagascar and Pakistan. Though the parasitoid was recovered from *Chilo partellus* at Rawalpindi (Pakistan) before the winter of 1968-69, it did not survive the cold season. However, the parasitoid was recorded to be well established in Madagascar on *Sesamia calamistis* (Mohyuddin 1970). In South Africa, 13 species of stemborer parasitoids from 11 countries were introduced between 1977 – 1993 for the control of the introduced pest, *Chilo partellus*, and other borer species, but apparently none seems to have established. Failure of establishment was attributed to harsh weather conditions during winter months and the fact that borers enter diapause in dry stalks for 7 months in winter (Kfir 1997). A number of reasons could be responsible for the failure of a natural enemy to establish in a new geographical area. These could be harsh climatic conditions, competition from native species, inaccurate identification of the pest in focus or the natural enemy to be introduced, host incompatibility or the release of low numbers of the enemy in the area of introduction (see Mackauer *et al.* 1990; Hopper & Roush 1993; Noyes & Hayat 1994; Schauff & LaSalle 1998). The theory that some natural enemies can be "habitat specific" rather than "host specific" has been postulated (Mohyuddin *et al.* 1981; Inayatullah 1983). For example, Carl (1962) found that female *C. flavipes* were not able to parasitize larvae of *Scirpophaga nivella* and *Chilo infuscatellus* when offered in cane stems, nor did he record field parasitism by *C. flavipes* in cane, though the parasitoid is recorded to parasitize *C. infuscatellus* in cane in Taiwan and India. Therefore he suggested that "racial differences" between populations within the same species is responsible. Similarly, *C. flavipes* was introduced into Pakistan from Japan in 1962. The parasitoid was recorded to have established in maize fields but was rarely recorded from stemborers in sugarcane. This led to the importation and release of different other "sugarcane adapted strains" of the same species from Thailand, Indonesia and Barbados, which resulted eventually in the establishment of the parasitoid (Mohyuddin *et al*. 1981; Mohyuddin 1990; Shami & Mohyuddin 1992). Other theories suggest the occurrence of two different strains of *Cotesia flavipes*, one adapted to sugarcane borer in the United States and the other to borers in Pakistan (Mohyuddin *et al.* 1981; Inayatullah 1983). However, this theory was challenged by Potting *et al.* (1997), who tested six different geographical strains of *C. flavipes* on the larvae of a number of stemborer species feeding on different host plants. Results from that study showed no differences in host selection behaviour among the different *C. flavipes* strains. The authors attributed the behavioural differences reported earlier to variations in reproductive successes of the different strains on the same stemborer hosts due to differences in physiological compatability between local parasitoid and host population. Therefore, prior to any release attempts of a natural enemy, a comprehensive study of its geographical distribution, host specificity, host range and history of introductions is required. In addition, a knowledge of the type of association between an introduced pest and candidate natural enemies for introduction is required; whether a natural enemy has no previous association with the pest, or alternatively, with a long history of association, is an important aspect to consider (see Smith & Wiedenmann 1997; Wiedenmann & Smith 1997). This paper reviews the distribution of the key stemborer species in Asia and Indian Ocean islands that may have the potential of invading Australia, and provides a catalogue of their old as well as new-association natural enemies recorded over the past 100 years. Hence, this list includes not only indigenous natural enemies but also exotic ones that were introduced into other countries and recorded to have been established. This information provides an overall picture of successful attempts of classical biological control against stemborers in Asia and Indian Ocean islands, thus will help in selecting the most suitable natural enemy in case of a pest incursion into Australia.

Moth borers can be loosely classified into three groups according to the part of the plant they usually attack: shoot borers; top borers or stalk borers, however a species may not be restricted to one part of the plant (Allsopp *et al.* 2000). The term "stemborer" is used here to include all species in those three groups. With the exception of *Emmalocera depressella* Swinhoe, which is a root borer, and *Angustalius malacellus* Duponchel, which feeds below soil levels, the rest of the species mentioned here feed inside the plant above ground level. Other sugarcane key pests such as *Eldana saccharina* (Walker) and *Diatraea* spp are major pests of sugarcane and other crops in Africa and central and South America respectively. Detailed information on biological control programs of *Eldana saccharina* can be found in Carnegie *et al.* (1985) and Conlong (1997).

Information on biological control of *Diatraea* spp can be obtained from Rodriguez-del-Bosque *et al*. (1990), Smith *et al.* (1993) and Smith (1994).

The followings are brief annotations on the most important gramineous pest species in Asia and Indian Ocean Islands, arranged alphabetically. Information on their economic importance, host range, geographical distribution and potential of invading Australia are also presented.

Family: Crambidae

***Angustalius* (*Bleszynskia*) *malacellus* Duponchel**

Very little information is available on this species which is an early-shoot borer that attacks sugarcane and corn. This species is recorded from Mauritius (Williams 1978), and Italy, where Zangheri & Furlan (1998) recorded a pest outbreak in the summer of 1997 on corn in Veneto, with over 50% of plants infested. Larvae bore into the young shoots below soil level and construct a gallery of silk and soil particules outside the shoot, which leads to a dead heart (Williams 1978). No records of natural enemies are available on this species. Potential of invading Australia is probably low to midium, and possibility of establishment in Australia is unknown.
Common names: the webworm.

***Chilo auricilius* Dudgeon**

This species is a pest of sugarcane in South East Asia and it is considered to be a major cane pest in Northern India (Neupane 1990). *C. auricilius* is distributed in China, India, Sri Lanka, Burma, Hong Kong, Bangladesh, Nepal, Taiwan, Vietnam, Formosa, Philippines, Thailand, Indonesia, Moluccas, Celebes, Borneo (Bleszynski 1970; Chundurwar 1989; David & Easwaramoorthy 1990). Kumar *et al.* 1987 stated that the expansion of planting soft but high sugar varieties, as well as excess usage of nitrogen fertilizers, caused this species to become a serious pest in the Bihar state of India. This species is also a major pest of sugarcane in western Uttar Pradesh (U.P.) in India since its appearance in 1954 (Atwal 1962; Rai *et al.* 1999). *C. auricilius* is recorded to infest plant cane and ratoon crops and these may serve as a source of infestation of the following plant crop. This species also feeds on rice and considered to be one of its important pests in Bangladesh (Husain & Begum 1985). *C. auricilius* is also reported to be a major pest of rice in some parts of India and Bangladesh (Neupane 1990), it is however regarded as a minor pest of rice in some parts of Papua New Guinea (Li 1990). This species was known to mainly feed on sugarcane in Indonesia until Hattori & Siwi 1986) reported it to feed on rice for the first time in Java and South Kalimantan. Female moths lay their eggs in clusters on the lower surface of sugarcane leaves, then first and second instars feed within the top leaf sheaths. Later larval instars bore inside cane stalks causing dead hearts. Other hosts also include maize and sorghum (Bleszynski 1970; Huang *et al.* 1985; Chundurwar 1989; Harris 1990).
Incursion potential of *C. auricilius* into Australia is high, and it also has a high colonisation potential in all sugarcane growing areas (Sallam & Allsopp 2002a).
Common names: Stalk borer, Gold-fringed rice borer, Gold-fringed stem borer, dark headed stem borer, sugarcane stalk borer.

***Chilo infuscatellus* Snellen**

This is a major pest of sugarcane, but also attacks maize, millet, sorghum, rice, barley, oat, juar, rarhi, batri (*Saccharum spontaneum*), ikri (*Saccharum fuscum*), *Panicum* species, *Rottboellia compressa*, *Cynodon dactylon*, *Echinochloa colonum*, *Cyperus rotundus* and Jove grass (*Rottboelia compressa*) (Bleszynski 1970). Due to heavy infestations with this pest, the Bihar State Planning Board of India declared North Bihar to be an endemic area for *C. infuscatellus* (Kumar *et al*. 1987). The pest is distributed in the Former USSR, Afghanistan, Tadzhikistan, Central Asia, China, Nepal, Korea, Taiwan, Pakistan, India, Bangladesh, Burma, Malaysia, Indonesia, the Philippines, Thailand, south Vietnam, Formosa, Sri Lanka, Java, Timor, Vulcan Island and Papua New Guinea (Carl 1962; Bleszynski 1970; CAB 1972; Chundurwar 1989; David & Easwaramoorthy 1990; Harris 1990; Neupane 1990). It damages sugarcane crops during the shoot stage as young larvae first feed on the outer leaves then later tunnel into the stem as third instars. (Easwaramoorthy & Nandagopal 1986; Harris 1990; Kuniata 1998). The pest is known to enter a diapause during winter in northern India, while in southern India the pest is present through out the year (Harris 1990). This species is considered to be a minor pest of sugarcane at Ramu and on Vulcan Island (PNG) where it attacks young plants and ratoon cane shoots. In 1981- 1982, two species of larval parasitoids were introduced to PNG from India by the Commonwealth Institute of Biological Control. These were *Bracon chinensis* (Szépl) and an Indian strain of *Apanteles flavipes*, which appears to be physiologically and behaviourally different from the indigenous strain in PNG. A number of 10,000 parasitoids of *B. chinensis* and 22,000 of *A. flavipes* have been released in the Ramu Valley but neither of them seem to have became established (Li 1990).

Common names: shoot borer, early shoot borer, sugarcane stemborer, sugarcane shoot borer, yellow top borer, striped stemborer.
C. infuscatellus has a high incursion potential into Australia due to its closeness to the mainland, and it also has a high colonisation potential in all sugarcane growing areas unless strict controls are imposed over movement of infested material (Sallam & Allsopp 2002a).

***Chilo orichalcociliellus* (Strand)**

This species is native to Africa where it attacks maize, sorghum, finger millet and sugarcane. Other wild grasses are also known to act as alternative hosts such as *Panicum maximum*, *Pennisetum purpureum* and other *Sorghum* species. In Kenya, this species is kown as the Costal Stalk Borer. Occurs in Kenya, Tanzania, Eritrea, Congo, Nigeria, Malawi, South Africa and Madagascar (Bleszynski 1970; Mathez 1972; Hill 1983; Polaszek 1998; Haile & Hofsvang 2001). *C. orichalcociliellus* may not however be an economic pest of sugarcane. The importance of this pest species has been declining in Africa since probably the 1970s due to the invasion of the exotic *Chilo partellus* (Overholt *et al.* 1997) into the continent. No recent data is available on the impact of this pest on sugarcane, and no information is available on its biological control outside mainland Africa. *Chilo orichalcociliellus* would have a medium potential of invading Australia (Sallam & Allsopp 2002a).

***Chilo partellus* (Swinhoe)**

This pest species is indigenous to Asia and has been recorded from Afghanistan, Pakistan, India, Bangladesh, Cambodia, Indonesia, Laos, Nepal, Sri Lanka, Thailand, Vietnam and the Philippines. The pest is recorded to have invaded Africa early last century, and the first report was from Malawi in 1932 (Tams 1932). Since then, the pest has spread across the African continent and is currently recorded from most countries in East and Southern Africa and the Indian Ocean islands of Madagascar and the Comoros (Ingram 1948; Bleszynski 1970; CAB 1989, Chundurwar 1989; Harris 1990; Meijerman & Ulenberg 1996; Maes 1998). *C. partellus* is mainly a serious pest of maize, sorghum and rice, but also attacks sugarcane when it is grown in the neighborhood of infested rice or maize fields (Bleszynski 1970). Hosts include pearl millet, finger millet, *Sorghum sudanense*, *S. vulgare*, *S. halepense*, *S. verticilliflorum*, Nachini (*Eleusinae coracaua)*, *Panicum maximum* and *Pennisetum purpureum*. (Chundurwar 1989). *C. partellus* is a major pest of maize, sorghum and rice in southern Asia but probably less important in sugarcane (David & Easwaramoorthy 1990; Neupane 1990). The most important crop losses often result from infestations developing during the early stage of crop growth leading to the formation of dead heart (Taneja & Nwanze 1989). Evidence over a 30 year period indicates that *C. partellus* is gradually displacing *C. orichalcociliellus* in some parts of the African continent. Ofomata *et al.* (2000), working in Kenya, found that *C. partellus* had a higher fecundity than *C. orichalcociliellus* at 25 and 28°C, though not at 31°*C*. In addition, *C. partellus* larvae develop faster than *C. orichalcociliellus* in maize and sorghum and consume more maize than *C. orichalcociliellus*, it is also able to terminate diapause faster than *C. orichalcociliellus*, though *C. orichalcociliellus* proved to survive better in napier and guinea grasses (Ofomata *et al.* 1999). The shorter developmental period of *C. partellus* seems to give this species a competitive advantage over the slower developing *C. orichalcociliellus*.
C. partellus has a medium potential of invading Australia due to its relative isolation, but would have a high colonisation and spread potential in all sugarcane-growing areas (Sallam & Allsopp 2002a).
Common names: spotted stemborer, spotted stalk borer, sorghum borer, sorghum stemborer, maize and sorghum stemborer, corn borer, jowar stem borer.

***Chilo polychrysus* (Meyrick)**

This is a very similar species to *Chilo auricilius* and confusion may exist where the two species overlap (Barrion *et al.* 1990). Li (1970) recorded this species as a minor pest of rice crops in Northern Territory, Australia. However, the occurrence of this species in Australia is an area that needs further investigation, as it was recently thought the species identified earlier as *C. polychrysa* (Meyrick) may have actually belonged to an identified species that is very similar to *C. polychrysus* (Ted Edwards, personal communicaton). *C. polychrysus* occurs in China, India, Thailand, Malaysia, Indonesia, Burma, Bangladesh, Vietnam and Papua New Guinea (Hattori & Siwi 1986; van Verden & Ahmadzabidi 1986; Harris 1990; Li 1990). In a survey on the complex of *Chilo* species on rice in the Philippines, *C. auricilius* accounted for 73% of the total number of specimens of the genus collected, while *C. polychrysus* was not recorded. The morphological similarity of the larvae and adults of these two species had led to earlier erroneous records of *C. polychrysus* in the Philippines, similar confusion may exist in other countries where the distributions of the two species overlap (Barrion *et al.* (1990). Bleszynski (1970) states that the ranges of the two species overlap in Indonesia, Thailand and India, however the two species can be easily separated by the genitalia of both sexes.

Rice is the main host but it also attacks maize and sugarcane though maybe of limited importance in this crop (David & Easwaramoorthy 1990). Hosts also include *Setaria* and *Cyperus* species. In Malaysia, *C. polychrysus* is found on *Oryza latifolia*, *Eriochola* sp. and *Panicum* sp (Kalshoven 1981). Frequent outbreaks of *C. polychrysus* in Peninsular Malaysia used to occur in rice fields before the introduction of double cropping of short-maturing varieties, currently *C. polychrysus* seized to be a major pest (Khoo 1986). Early instar larvae cause irregular holes on the cane leaf sheath and older larvae bore into stems. In the Northern Territory, life cycle of *C. polychrysus* takes about 54 days and the insect completes six overlapping generations per year if rice is grown all year round (Li 1990). Li (1990) states that the incidence of *C. polychrysus* is low in rice crops at Tortilla Flats in the Northern Territory during both dry and wet seasons. This insect does not seem to inflict high rates of damage to rice, and apparently of far less importance in cane (Khoo 1986). Li (1970) reports *Apanteles flavipes* Cam as a larval parasitoid, which he also referres to as *A. nonagriae*. He also lists *Euchalcidia* sp. (Hymenoptera: Chalcididae) as a pupal parasitoid.

C. polychrysus may have a high colonisation and spread potential in cane-growing areas of Australia. The possibility of the Northern Territory population surviving on cane plants should be investigated (Sallam & Allsopp 2002a).

Common names: Dark headed stemborer, dark-headed rice stemborer of southeastern Asia.

***Chilo sacchariphagus* (Bojer)**

This is a synonym of *Chilo venosatus* (*Proceras venosatus*) Walker. *C. sacchariphagus* is a major pest of sugarcane in China, India, Indonesia, Madagascar, Mauritius (where it was accidentally introduced from Java in 1850) and Taiwan. *C. sacchariphagus* also attacks sorghum and considered to be one of its important pests in some parts of China (Chundurwar 1989). It also occurs in Reunion and the Comoros, Borneo, Java (where it occurs below altitudes of 800m), Bali, Sumatra, Celebes, Japan, Singapore, Sri Lanka, Malaysia, Thailand and the Philippines (Bleszynski 1970; Kalshoven 1981; Williams 1983; Facknath 1989; David & Easwaramoorthy 1990; Leslie 1994; Ganeshan and Rajabalee 1997; Suasa-ard 2000). It has been recently recorded for the first time on main land Africa from Mozambique (Way and Turner 1999). This species is oftenly treated as three "sub-species": *Chilo sacchariphagus stramineellus* (Caradja), *Chilo sacchariphagus sacchariphagus* (Bojer) and *Chilo sacchariphagus indicus* (Kapur). *C. sacchariphagus* infests the plant as it starts forming internodes until harvest time. Female moths lay their eggs in clusters on both surfaces of the leaves of sugarcane. First larval instars feed mainly on leaves and leaf sheaths then later borrow inside the soft growing point of stalks resulting in dead hearts (David 1986). In India, *C. sacchariphagus* was reported to cause 10.7% loss in cane yield (Agrawal 1964). Incursion potential of *C. sacchariphagus* into Australia is medium, but the pest is readily transmitted on infected planting material, and would have a high spread and colonisation potential in all sugarcane-growing areas (Sallam & Allsopp 2002a).

Common names: sugar-cane stalk borer; sugarcane internode borer, striped sugarcane borer, the spotted borer, spotted stem borer, internode borer, internodal borer, stalk borer, sugarcane spotted borer.

***Chilo suppressalis* (Walker)**

This species is a major pest of rice in East Asia, India, Japan and Indonesia. *C. suppressalis* is reported mainly on rice from Zanzibar, Iraq, part of the former USSR (Soviet Maritime Province), China, Japan, Korea, Taiwan, Bangladesh, Brunei, Burma, India, Pakistan, Malaysia, Indonesia, Nepal, the Philippines, Sri Lanka, Thailand, Vietnam and PNG. Also recorded from Hawaii and Spain where it was accidentally introduced (Subba Rao & Chawla 1964; Harris 1990). Li (1970) recorded this species on rice in the Northern Territory of Australia (see also CAB 1977). Rice is the main host, however, David & Easwaramoorthy (1990) referred to this species as a minor pest of cane in Taiwan and Japan. Other hosts may include sorghum, *Panicum miliaceum*, *Echinochloa* spp., *Phragmites communis*, *Saccharum fuscum*, *Typha latifolia*, water oats (*Zizania latifolia*) and *Zizania aquatica* (Litsinger 1977; Harris 1990; Ishida *et al.* 2000). However, a recent study by Cuong & Cohen (2002) demonstrated that many records of this species from non-rice host plants are doubtful and is probably based on occasional observations, and thus, *C. suppressalis* is not considered to be of any economical importance in sugarcane. The pests presence is confirmed in Australia, but not in commercial cane areas; survivial of the Australian population on cane plants may be an area worth investigating.

Common names: Rice *Chilo*, striped stem borer, Asiatic rice borer.

***Chilo terrenellus* Pagenstecher**

This species is native to Papua New Guinea where it's recorded as a pest of sugarcane, and it is also recorded from Bismarck Archipelago and Vulcan Island (Bleszynski 1970; Li 1985a; Kuniata 2000). *C. terrenellus* was first recorded in Australia on the Torres Strait islands of Saibei (Gough & Peterson 1984; Chandler & Croft 1986; see also Li (1990) and Dauan (Anon. 1996). This species is a pest of sugarcane in the

Markham Valley and at Ramu (PNG), and it also attacks two species of wild cane (*Saccharum robustum* and *S. edule*). The status of *C. terrenellus* in PNG has changed in the late 1980s due to the rapid adoption of "Ramu stunt" resistant cultivars, which on the same time were *Sesamia* susceptible. Since 1987, severe cane losses were sustained due to *Sesamia grisescens*, while losses in young cane shoots due to *C. terrenellus* is usually less than 10%, but infestation may be exacerbated if diseases such as red rot (*Colletotrichum falcatum*) invades the wounds (Li 1990). Li (1985a) studied the life cycle of this species in the field and reports six overlapping generations a year.
The probability of this species invading Australia is high, regarding the fact that it is found on the Torres Strait islands to the immediate north of Australia (Sallam & Allsopp 2002a). Though the significance of *C. terrenellus* maybe far less than that of the noctuid *Sesamia grisescens* in PNG (Kuniata 2000), its status may change if it invades Australia depending on the varietal structure of the area invaded, and could potentially cause significant damage to Australian cane.

***Chilo tumidicostalis* (Hampson)**

This species is reported to feed exclusively on sugarcane, found in Bangladesh, Burma, India (Assam and Bengal), Nepal and Thailand (Bleszynski 1970; Miah *et al*. 1983; David & Easwaramoorthy 1990; Suasa-ard 2000). In India, where it's known as the Bengal borer, it used to be considered a major pest of sugarcane in Purnea and adjoining parts of Bhagalpur, Munger and Darbhanga districts of Bihar, but its importance seems to have declined during the 1980s (Kumar *et al*. 1987). However in Thailand, *C. tumidicostalis* used to be considered a minor pest of sugarcane until the late nineties, when it unexpectedly became the most important pest of cane. Severe outbreaks were reported in the provinces of Sa Kaew and Buri Rum where infestation reached 100% (Suasa-ard 2000). Adult moths lay their egg masses on the lower surface of the top leaves and larvae soon tunnel into the soft tissues of the growing point. Later larvae disperse either to another healthy plant or to the lower healthier parts of the same stalk causing a secondary infestation (Neupane 1990).
Incursion potential of *C. tumidicostalis* into Australia is medium due to its relative isolation from the main land, however the pest would have a high spread and colonisation potential in sugarcane-growing areas specially in North Queensland (Sallam & Allsopp 2002a).
Common names: The Plassey borer of sugarcane.

Family: Noctuidae
***Sesamia calamistis* Hampson**

This species is mainly found in sub-Saharan Africa and on Indian Ocean islands. It is recorded in South Africa, Malawi, Zimbabwe, Uganda, Tanzania, Kenya, Angola, Nigeria, Ivory coast, Cameroon, Senegal, Gambia, Ghana and the Indian ocean islands of Madagascar, Mauritius, Reunion and Zanzibar (Meijerman & Ulenberg 1996, Holloway (1998). Its host plants include rice, maize, sorghum, millet, sugarcane, *Panicum maximum*, *Paspalidium paniculatum, Paspalum conjugatum* (sourgrass), *Paspalum urvillei* (vasey grass), *Pennisetum purpureum*, *Rottboellia exaltata*, *Setaria* spp., *Sorghum arundinaceum*, *Tripsacum laxum*, *Typha domingensis* (narrowleaf cumbungi, bulrush) and *Vetiveria zizanioides* (vetiver), (Tams and Bowden 1953; Nye 1960; Harris 1962; Meijerman & Ulenberg 1996). Maize is the preferred host plant (Heinrichs 1998), but the species is frequently found on sugarcane in Africa, though rarely of economic importance on this crop. Larvae are able to attack both mature and young cane, but damage tends to be confined to young shoots and plants can compensate by tillering, therefore damage to cane is minimal under normal conditions. In wet, tropical areas the life cycle is practically continuous throughout the year, while drought or cold temperatures may slow development. Mature larvae become inactive from the start of the dry season and remain so until the rains begin, while development continues uninterrupted under irrigation. There are five to six generations each year in most of West Africa to three in the drier Sahel region. In South Africa, light trap catches show an annual pattern with peaks in numbers during April-May and again in September-October (see Carnegie & Leslie 1991; Leslie 1994; Polaszek & Khan 1998).
Common names: Pink stalk borer, pink borer.
Entry potential of *Sesamia calamistis* to Australia is medium, but will have a high colonisation potential in all sugarcane-growing areas (Allsopp & Sallam 2001).

***Sesamia cretica* Ledrere**

This species is recorded from France, Italy, Croatia, Greece, Morocco, Algeria, Egypt, Sudan, Ethiopia, Somalia, northern Kenya, northern Nigeria, Syria, Tadzhikistan, Iraq, Iran, Saudi Arabia, Yemen, India, Sri Lanka and Thailand. Host plants include hybrids of sugarcane, rice, millet, sorghum, Johnson grass, wheat, maize, oat, barley and Tomato (Tams & Bowden 1953; Rao & Nagaraja 1969; Leslie 1994; Meijerman & Ulenberg 1996; FitzGibbon *et al.* 1998; Holloway 1998). Larvae feed on leaves, stems and ears of maize (El-Amin 1984; Shojai *et al.* 1995). This species is considered to be the most serious of the maize and sugarcane stemborers in Egypt. Larvae attack maize and sugarcane plants shortly after emergence. Early instar larvae devour the whorl leaves resulting in the death of the growing point and causing dead hearts. Later instar larvae damage older plants by excavating tunnels into the stem, corn ears and cobs (Soliman & Miham 1997). On sugarcane, this species has characteristically been thought of as a shoot borer (Temerak & Negm 1979), but it can damage more mature stalks (El-Amin 1984). In Iran, *S. cretica* is reported to cause an average annual damage of about 20 to 30% in corn and may reach 70% during population outbreaks (Shojai *et al.* 1995). While infestation in Egypt may cause complete death of small corn plants by April-May (Soliman & Miham 1997).

S. cretica has a low-medium entry potential to Australia due to geographical isolation, but may have a high colonisation potential in all sugarcane-growing areas (Allsopp & Sallam 2001).

Common names: Durra stem borer, corn stem borer, pink borer, pink stalk borer, greater sugarcane borer.

***Sesamia grisescens* Warren**

This species is geographically restricted to its native home (Papua New Guinea), where it occurs from sea level to 1600 m above sea level in PNG. *S. grisescens* primarily feeds on indigenous *Saccharum* species such as *S. robustum*, *S. spontaneum* (wild cane) and *S. edule* (pitpit), along with other wild grasses such as *Panicum maximum* and *Pennisetum purpureum* (Young & Kuniata 1992; Lloyd & Kuniata 2000). *S. grisescens* has become a major pest of sugarcane in Papua New Guinea due to the change to cultivation of cane varieties that are resistant to Ramu Stunt but on the same time were "*Sesamia*–susceptible". Adult females readily oviposit and larvae complete their development in sugarcane at any growth stage (Kuniata & Sweet 1994). Early larval instars feed voraciously in the upper three internodes of the stalk leading to killing the growing point and rotting of the top and resulting in dead hearts. Fourth and fifth instars migrate to healthy stalks and continue feeding inside the upper internodes. Infestation also encourages sugarcane weevil borer, *Rhabdoscelus obscurus* (Biosduval), along with fungal and bacterial diseases to attack the damaged parts of the stalk resulting in stalk rotting and juice deterioration (Kuniata 1998, 2000; Lloyd & Kuniata 2000). At Ramu, estimated losses are 0.82 tonnes of cane per hectare, 0.13 tonnes of sugar per hectare and 0.15% pol for every 1% of bored and rotting stalks (Eastwood *et al.* 1998; Kuniata 1998). Larval feeding results in increased fibre, glucose, fructose and raffinose contents and reduces the glucose/fructose ratio. Processing of this low-quality cane results in higher production of molasses and a consequent need for extra storage facilities (Eastwood *et al.* 1998). Bored cane also increases harvesting costs (Kuniata 1998, 2000). Kuniata (2000) estimated that damage must be well below 20% bored and rotting stalks for cost-effective extraction of sucrose.

In PNG, *Apanteles flavipes* (*Cotesia flavipes*) occurs naturally where it parasitises medium- large larvae of *Sesamia* and *Chilo* species and is reported to give up to 70% parasitism of *S. grisescens* in the field. However, in 1981-1982, an Indian strain of *C. flavipes* was introduced to PNG to increase the natural suppression of the stemborer species complex. The Indian strain was reported to have failed to establish (Li 1990; Lloyd & Kuniata 2000). This however requires thorough investigation since the two *C. flavipes* strains may have been able to interbreed in the field.

In 1991, the pupal parasitoid *Pediobius furvus* Gahan (Eulophidae) was imported from East Africa and released in PNG against this pest where it gives variable parasitism rates. Routine releases of the two parasitoids are conducted in PNG against *S. grisescens* to increase natural suppression of the pest and minimize the use of pesticides (Kuniata 1999). *S. grisescens* has a high entry potential into Australia, and will have a high colonisation potential in all Australian sugarcane-growing areas, specially in North Queensland, unless strict controls are imposed over movement of infested material (Allsopp & Sallam 2001).

***Sesamia inferens* Walker**

This species is a notorious pest of sugarcane in Okinawa Prefecture in Japan and an important pest of rice in the Indian sub continent (Kumar & Kaul 1997). Occurs in Japan, Pakistan, India, Sri Lanka, Taiwan, China, Korea, Burma, Nepal, Bangladesh, Cambodia, Vietnam, Laos, Thailand, the Philippines, Malaysia, Singapore, Indonesia, Papua New Guinea and Solomon Islands (CIE 1967; Rao and Nagaraja 1969; Kalshoven 1981; David *et al.* 1991; Cheng 1994; Kuniata 1994; FitzGibbon *et al.* 1998, Teetes *et al.* 1983; Hattori & Siwi 1986; Chundurwar 1989; Suasa-ard 2000). *S. inferens* attacks a wide range of gramineous plants such as wheat, maize, oats, millet, reed as well as other wild grasses such as Guinea grass, Johnson grass, Sudan grass and lemon grass. It is also reported to attack bananas and seedlings of oil palm (Shah & Garg 1986; Garg 1988; Hirai 1991; Alam *et al.* 1993; Li 1993; Jacob & Kochu 1995), and it is recorded as an important pest of rice in Bangladesh (Husain & Begum 1985; Shahjahan & Talukder 1995). Corn and upland rice are favoured hosts in South Eastern Asia, and development on sugarcane is slower than on those species (Kalshoven 1981). Trials in India showed that maximum survival of *S. inferens* is achieved on maize (corn) followed by sorghum, and that sugarcane was the least preferred, which may explain the low economic

importance of this species in cane crops in India (Tyagi & Sharma 1989). In Taiwan, 23.6% of dead hearts in young cane in autumn were caused by this species, although only 0.5% internode infestation of millable cane was recorded (Cheng 1994).
The entry potential of *S. inferens* and its colonisation potential in Australia is high due to that fact that it is geographically close to Australia, and readily transmitted on infested planting material (Allsopp & Sallam 2001).
Common names: Purple stemborer.

Sesamia nonagrioides **Lefebvre**

This species is a similar species to *S. calamistis*. It is distributed in the Azores, Canary Islands, France, Greece, Turky, Israel, Iran, Italy, Portugal, Spain, Ghana, Ivory Coast, Nigeria, Togo and Sudan. Host plants include Maize, rice, sorghum, sugarcane, *Chasmopodium afzelii*, *Pennisetum purpureum*, *Rottboellia exaltata* and *Sorghum arundinaceum* (Tams & Bowden 1953; Meijerman & Ulenberg 1996). In Morocco, feeding by *Sesamia nonagrioides* results in reduced sucrose and increased dextran (glucose) content of the juice (Hilal 1985), however, sugarcane does not seem to be a preferred host to this pest in Morocco; larvae feeding on wheat and especially sugarcane show a slow development rate and high mortality, which may explain the comparatively low larval density found on sugarcane as compared to corn in Morocco (Hilal 1984). No data is available on the biological control of this species in Asian countries, however, *Platytelenomus busseolae* (*Telenomus busseolae*) is recorded to be an active egg parasitoid of this pest in maize fields in Turkey (Sertkaya & Kornosor 1994). *S. nonagroides* has a medium entry potential to Australia (Allsopp & Sallam 2001).

Sesamia penniseti **Tams & Bowden**

This species is very similar to *S. calamistis*, *S. nonagrioides* and *S. poephaga*, but mainly distributed in West Africa, and more frequently found in forest localities than *S. poephaga* (Tams & Bowden 1953; Holloway 1998). Host plants include *Oryza sativa* (rice), *Panicum maximum* (Guinea grass), *Pennisetum glaucum* (pearl millet), *Pennisetum purpureum* (elephant grass), *Saccharum* spp. hybrids (sugarcane), *Setaria splendida*, *Sorghum bicolor* (sorghum) and *Zea mays* (corn) (Harris 1962; Rao & Nagaraja 1969; Meijerman & Ulenberg 1996, 1998; Heinrichs 1998). Larvae tend to bore in young cane shoots causing typical dead heart symptoms, and though it is common in *Pennisetum puprpureum*, it is of little economic importance in maize (Tams & Bowden 1953). *S. penniseti* has a medium entry potential to Australia (Allsopp & Sallam 2001).

Sesamia poephaga **Tams & Bowden**

This is a very close species to *S. calamistis* and *S. nonagrioides*. Host plants include Maize, sorghum, sugarcane, *Panicum maximum* (Guinea grass) and *Pennisetum purpureum* which is the usual food plant (Tams & Bowden 1953; Harris 1962). *S. poephaga* is mainly found in Africa where it is recorded from Ghana, Ivory coast, Kenya, Malawi, Nigeria, Sudan, Tanzania, Uganda, Togo, Zimbabwe, Comoros and Madagascar (Tams & Bowden 1953). This species may cause some significant damage to maize and sorghum, but it is less important on sugarcane. No records of natural enemies are available from the Indian Ocean islands of Comoros and Madagascar. This pest has a low-medium entry potential to Australia (Allsopp & Sallam 2001).

Sesamia uniformis **(Dudgeon)**

Sesamia uniformis is reported from Northern India, Pakistan and the Philippines (Rao & Nagaraja 1969), though the record of Philippines appears doubtful. Host plants include *Oryza sativa* (rice), *Erianthus arundinaceus*, *Saccharum spontaneum*, *Saccharum* spp. hybrids (sugarcane), *Sorghum bicolor* (sorghum), *Triticum aestivum* (wheat) and *Zea mays* (corn) (Rao & Nagaraja 1969). Very little is known about this species and it is perhaps a synonym of *S. cretica* (Polaszek 1998). Young larvae feed in the spindle and shoots of sugarcane, while older larvae bore in the top section of the stalk. Apparently not considered a species worth controlling in sugarcane. Potential of invading Australia is medium (Allsopp & Sallam 2001).

Family: Pyralidae

Acigona steniellus **(*Bissetia steniella*) Hamp**

Little is known about this species, which seems to have a restricted geographical distribution of only India and Pakistan and feeds exclusively on sugarcane plants (Halimie *et al.* 1994; Pandey *et al.* 1997b). *A. steniellus* seems to be a manageable pest in cane fields and rarely causes significant losses. Jolly & Singh (1990) reported that removing and destroying infested sugarcane shoots at weekly intervals from July to September for several years was found to be an effective method of controlling the pest in both upland and lowland sugarcane growing areas in India. Similarly in Pakistan, mechanical removal through shoot cutting

significantly reduced infestation (Halimie *et al.* 1989). *A. steniellus* may have a low- medium potential of colonising and spreading in Australia due to its isolation from the main land. The impact of incursion of this species on sugarcane in Australia is difficult to predict.
Common names: Gurdaspur borer.

***Emmalocera* (*Polyocha*) *depressella* Swinhoe**

This species is a root borer, where it feeds inside cane roots and the underground parts of cane stems. Due to the nature of infestation by this species, information on life stages, pest incidence and yield losses are still not fully established (Singh *et al.* 1996). *E. depressella* was recorded damaging sugarcane roots for the first time in Tamil Nadu (India) in a ratoon crop in December 1989 (Alagesan *et al.* 1991). The authors record up to 30% of crop infestation especially on light soils in drought-prone areas. However the pest has been recorded earlier from other parts of India (Box 1953). *E. depressella* is also recorded from Pakistan (Khan & Jan 1994; Ashraf & Fatima 1996) and Bangladesh (Kundu *et al.* 1994). Sugarcane is the main host but it was also recorded for the first time feeding on sorghum in Karnal (India) by Sardana (1999).

In India, *E. depressella* larvae were recorded to start hibernation in cane stalks at an average depth of 3.4cm in November – December until March. Emergence of adults started around April, with 31-34°C being the optimum temperature range for their activity, and adult activity was very poor at temperatures below 15°C (Sardana 1996; Sardana 1997a; Sardana 1998). In another study by Pandya *et al.* (1996) at Navsari in south Gujarat, India, *E. depressella* eggs were laid on the under-surface of the leaves, with an egg laying capacity of 200- 325 egg per female. Eggs hatched in 5-7 days and the larval period ranged between 57-96 days showing 9 instars. Pupal period ranged from 9 to 11 days and pupation took place in the damaged portion of the cane. Total life period from egg to adult ranged from 76 to 120 days. Infestation is sometimes accompanied by root rot caused by *Fusarium moniliforme*, which causes wilt disease. Combined infestation and infection increases yield losses and decreases juice quality (Sardana 1993; Sardana *et al.* 2000). Potential for incursion by this species into Australia is medium due to its relative isolation from Australia, but the pest would rapidly colonise many cane growing areas and may have a high spread potential in Australia.
Common names: sugarcane rootstock borer.

***Maliarpha separatella* Ragonot**

This species is mainly a pest of cultivated and wild rice. *M. separatella* is found on mainland Africa and Indian Ocean islands (Madagascar, Comoros, Mauritius and Reunion). It is also reported from Indonesia and PNG, and may occur in Burma and China (Young 1982; Li 1985a; Maes 1998; Ooi 1998). Though *M. separatella* is known to feed exclusively on rice, Li (1985a) recorded heavy damage to sugarcane stems in the Markham valley of PNG due to this species. Therefore the status and host range of this species in PNG requires adequate revision. Cook (1997) proposed that *M. separatella* is a complex of three closely related stemborers, and the species has a number of synonyms (*Enosima* (*Rhinaphe*) *vectiferella* Ragonot and *Anerastia* (*Ampycodes*) *pallidicosta* Hampson (see also Maes 1998). No natural enemies however where reported from PNG. One active parasitoid species of *M. separatella* in main land Africa is *Goniozus indicus*, which was introduced into Madagascar from Senegal in 1973 for the control of this species (Appert 1975). *M. separatella* apparently has a high potential of colonising and spreading in Australia due to its presence in Indonesia and PNG.
Common names: African white stemborer, African white rice borer, White stemborer.

***Scirpophaga nivella* (Fabricius)**

This species is mainly a pest of rice. Its status in sugarcane as a pest is now doubtful, since Lewvanich (1981) stated that *S. nivella* does not occur in cane, and mostly all records of this species in cane are referrable to *Scirpophaga excerptalis*. However, several recent references, specially from China and Indonesia, are available on this species as a pest of cane. It is therefore important to realize that the status of the species in cane has to be revised. The Checklist of the Lepidoptera of Australia (Nielsen *et al.* 1996) uses the name *chrysorrhoa* as an alternative species name for *Scirpophaga nivella.* Under that name, Common (1960) indicates that its found in Northern Australia, extending southwards along the eastern coast to northern NSW. Specimens examined by Common (1960) from Australia were collected from Ayr, Bowen, Brisbane, Cairns, Cape York, Dunk Island, Halifax, Mackay, Stewart River, Silver Plains (Cape York Peninsula) and Townsville in Queensland; Brunswick Heads and Burringbar in New South Wales; Ivanhoe in Western Australia and Bathurst Island, Darwin, Groote Eylandt, Humpty Doo, Marraki, Mary River, Melville Island and Stapleton in the Northern Territory. Outside Australia, this species is recorded from Bangladesh, Borneo, Hong Kong, India, Indonesia, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam (Cheng 1999; Arora 2000). The fact that *Scirpophaga chrysorrhoa* in Australia is the same species

as *S. nivella* in Asia requires further examination. However, the Australian population is highly unlikely to be of any potential threat to cane, since there have been no records of this species in Australian sugarcane fields.
Common names: Rice stemborer, Top borer of sugarcane, White top moth borer.

***Scirpophaga excerptalis* Walker**

This species is found in Bangladesh, Bhutan, China, India, Indonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, PNG, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam (Miah *et al.* 1983; Arora 2000; Kuniata 2000; Suasa-ard 2000). *Scirpophaga excerptalis* is mainly a pest of sugarcane. Other hosts include *Chloris barbata*, *Echinochloa colona*, *Erianthus arundinaceum*, *E. munja*, *E. ravennae*, *Naranga prophyrocoma*, *Panicum* sp., *Pennisetum purpureum*, *Saccharum spontaneum*, *Sclerostachya fusca*, *Sorghum bicolor* and *Sorghum halepense* (Arora 2000). *S. excerptalis* causes significant damage to sugarcane in subtropical north India, where recent outbreaks were reported due to the increase in the area of sugarcane under well irrigated conditions and late harvest of the crop. Improper timing of pesticide application and the use of sub lethal doses have also contributed to the increase in the pest problem (Tanwar & Varma 1997). Shenhmar & Brar (1996a) refer to this species as one of the key pests of sugarcane in the Punjab, where it is active from March to October but most of the damage is seen in July – August. Madan *et al.* (1999) estimated up to 44.0% yield losses and 2.0 units of sugar in India. Common symptoms of infestation are the appearance of parallel rows of "shot holes" on leaves, a red streak caused by mining inside the mid-rib, deadhearts and a bunchy top appearance of shoots (Arora 2000). It is important to realize that this species has for a long time been erroneously referred to as *Scirpophaga nivella*. Lewvanich (1981) states clearly that *S. nivella* does not occur in cane, which pauses a question mark regarding the status of *S. nivella* as a cane pest. In addition, Arora (2000) refers to this confusion of identity and states that a large number of specimens identified as *S. nivella* has been re-examined in India and found to be *S. excerptalis*. However, he states that about 35 male and female specimens present in the Indian Institute of Sugarcane Research (IISR), Lucknow, were found to be true *S. nivella* that were collected form sugarcane fields. It is also important to realise that no further records of *S. nivella* in cane have been made at the IISR in Lucknow since 1972. Hence, a survey of pyralids in cane fields of Lucknow (where the insects were collected) is envisaged by Indian entomologists to establish whether *S. nivella* is in fact associated with sugarcane. The confusion in the identity of *S. excerptalis* and *S. nivella* was resolved by Lewvanich (1981), yet many recent references still refer to *S. nivella* as a pest of cane in Asia. *S. excerptalis* has a high entry potential into Australia, and a high colonisation potential in all Australian sugarcane-growing areas.
Common names: Sugarcane top borer.

Family: Tortricidae

***Tetramoera* (*Argyroploce*) *schistaceana* (Snellen)**

This species is an early-shoot borer, mainly on sugarcane, found in Mauritius, Reunion, Sri Lanka, China, Taiwan, Japan, Vietnam, Malaysia, the Philippines and Indonesia (Williams 1978; Allsopp *et al.* 2000). Infestation by this borer causes dead heart, and older shoots are sometimes attacked. Guo *et al.* (2000) recorded *T. schistaceana* as a dominant pest in sugarcane plantations in Zhanjiang, Guangdong, China in recent years, where it occurs coincidentally with *Chilo infuscatellus* and *C. sacchariphagus*. Guo *et al.* (2000) stated that infestation is mainly concentrated on the 3-15 internodes of cane plants and recorded frequent infestation ranging between 53.67-72.58%. Lower damage rates are recorded from Taiwan (Cheng 1999). *T. schistaceana* is frequently controlled using *Trichogramma* and *Trichogrammatoidea* in China, Taiwan and the philippines (Pan & lim 1979; Liu *et al.* 1987; Alba 1991). This potential of species to invade Australia is probably medium due to its isolation from the main land, but may be able to readily spread in all cane growing- areas.
Common names: The white sugarcane borer, the gray borer, sugarcane shoot borer.

Lepidopterous borers in Australia

The noctuid, *Bathytricha truncata* (Walker), and the gelechiid, *Ephysteris promptella* (Staudinger), are the only lepidopterous borers of sugarcane recorded in cane fields in Australia. The two species are minor pests of cane in Australia and rarely cause significant damage.

***Bathytricha truncata* (Walker)**

This species is distributed in New South Wales and Queensland in rice, sugarcane, *Echinochlea* spp., *Typha* spp., *Cyperus* sp., paspalum and water couch (Jones 1966). Larval instars feed inside the growing point of young cane plants causing dead hearts. Li (1970) lists some unidentified larval and pupal parasitoides reported to attack this pest in Australia. Bell (1934) also reports *Apanteles flavipes* (*nonagriae*) as a larval parasitoid collected in the Mackay district. One pupal parasitoid was identified as *Euplectrus howardi*

(Eulophidae) (Jarvis 1927). Macqueen (1969) and Li (1970) mention that *B. truncata* had become economically important in sugarcane in Queensland due to the destruction of its natural enemies as a result of the use of dieldrin for the control of soldier fly. Recently this species is rarely seen in Australian cane fields. Common names: Large moth borer, rice stem borer.

Ephysteris promptella **(Staudinger)**

Larvae of this species bore into young shoots, often killing them and causing dead hearts. Damage is restricted to ratoons and severe damage has always been reported to occur under drought conditions. Jarvis (1927) stated that no natural enemies are recorded on this pest and suggested that this could be because it is an introduced species, probably from Natal, Indonesia. The pest is also reported to attack maize and sorghum in South Africa (Drinkwater 1986).

Jarvis (1927) also refers to a pyralid shoot borer, *Fossifrontia* (*Polyocha*) sp., which caused dead hearts in cane ratoons and gave similar damage symptoms to *B. truncata* or *E. promptella*. No further records are available on this species, which was mainly collected by Edmund Jarvis from a cane field at Pyramid, Far North Queensland, in (1920.

In addition, Sallam & Allsopp (2002b) recorded minor damage in a ratoon crop on the Atherton Tableland in the summer of 2000. Failed plants were dug up to investigate the cause of damage, and about 20 larvae of *Oncopera* sp., possibly *Oncopera mitocera*, were collected per stool, but there was no evidence that the damage is caused by the larvae. In the laboratory, collected larvae fed on cane setts but never on the shoots. The larvae did not complete their life cycle in the laboratory, therefore the cause for failed ratooning was attributed to possible harvest damage.

The following table presents all records made of natural enemies of gramineous stemborers in Asia and Indian Ocean islands over almost the last century. It should be noted that a number of scientific names have been changed or revised and corrected. For example, the species previously referred to as *Apanteles* (*Cotesia*) *flavipes* Cameron (Hymenoptera: Braconidae) is now known to be a complex of species that are morphologically similar but distributed in different geographical parts of the world, and these are *Cotesia flavipes*, *C. sesamiae* and *C. chilonis*. In addition, parasitoides and predators of sugarcane pests in India were listed by Butani in 1958 and later by the same author in 1972, during this period, some names have been changed and others that were erroneously applied to various species have been corrected. Information from the two lists is presented here to account for these inconsistencies. Moreover, some of these records may have been incidental, therefore natural enemies of doubtful status or those recorded to exploit a certain host only in the laboratory were not included in the list. Some pests such as *Chilo partellus* and *Sesamia calamistis* are widely distributed in main land Africa, while others such as *Sesamia critica* extend to Southern Europe, but only natural enemies recorded on them in Asia and Indian Ocean islands are presented in this list. Information on natural enemies of these pests in main land Africa can be found in (Polaszek 1998).

Host	Family	Natural enemy	Country	Reference	Stage attacked	Host plant	Remarks
Family: Crambidae							
***Chilo auricilius* Dudgeon**							
Parasitoids							
	Braconidae	*Allorhogas pyralophagus* Marsh	India	Shenhmar *et al.* (1990)	L	Sugarcane	Introduced from Mexico, recorded to have been established in release sites.
	"	*Apanteles* sp.	Indonesia	Tan & Koh (1980)	L	Sugarcane	
		Apanteles Baoris Wilkinson	India	Butani (1972)	L	Sugarcane	
		Apanteles ruficrus Hal.	India	Nigam (1984)	L	Sugarcane	First record on this host in India.
	"	*Cotesia flavipes* Cameron	India	Butani (1972)	L	Sugarcane	
				Nagarkatti & Nair (1973)		*Sacciolepis interrupta*[*]	
				Nigam (1984)		Sugarcane	
				Nair (1988)		Sugarcane	
			Indonesia	Mohyuddin (1992)		Sugarcane	Imported strain from Thailand (in (1985)[*].
				Sunaryo & Suryanto (1986)		Sugarcane	
				Samoedi (1989)		Sugarcane	
	"	*Campyloneurus* spp.	Indonesia	Tan & Koh (1980)	L	Sugarcane	
				Samoedi (1989)		Sugarcane	
	"	*Campyloneurus mutator* Fabricius	India	Butani (1972)	L	Sugarcane	
	"	*Stenobracon deesae* Cameron	India	Butani (1958)	L	Sugarcane	
	"	*Tropobracon* (*Shirakia*) *schoenobii* (Viereck)	India	Butani (1972)	?	Sugarcane	
	"	*Vipio* (*Stenobracon, Bracon, Glyptomorpha*) *deesae* (Cameron)	India	Butani (1972)	L	Sugarcane	
	"	*Vipio* sp.	India	Butani (1972)	L	Sugarcane	
	Eulophidae	*Tetrastichus israeli* Mani & Kurian (*Aprostocetus israeli* Mani)	India	Butani (1972)	P	Rice	
	Eupelmidae	*Eupelmus* sp.	India	Butani (1972)	L?	Rice	
	Ichneumonidae	*Amauromorpha metathoracio schoenobii* Viereck	India	Butani (1972)	L	Sugarcane	
		Centeterus alternecoloratus Cushman?	India	Chacko & Rao (1966)	P	Rice	Parasitism levels of up to 23% were recorded in Assam, India.
		Centeterus alternecoloratus Cushman	India	Butani (1972)	P	Rice	
		Cremastus (*Trathala*) *flavo-orbitalis* (Cameron)	India	Butani (1972)	L	Rice	
		Gambroides sp.	Indonesia	Tan & Koh (1980)	P	Sugarcane	
		Xanthopimpla sp.	Indonesia	Tan & Koh (1980)	P	Sugarcane	

[*] A perennial grass found in damp areas, a pest of rice plantations in some parts of India.
[*] Prior to the importation of the Thai strain into Indonesia, Mohyuddin (1992) found that *Chilo auricilius* larvae used to encapsulate immatures of the Indonesian *C. flavipes*.

		Xanthopimpla stemmator Thunb.	Indonesia	Samoedi (1989)	P	Sugarcane	
	Scelionidae	*Telenomus* sp.	Indonesia	Tan & Koh (1980)	E	Sugarcane	
	Tachinidae	*Diatraeophaga striatalis*	Indonesia	Samoedi (1989)	L	sugarcane	Mass released.
	"	*Sturmiopsis inferens* Townsend	India	Butani (1972)	L	Sugarcane	
				Chandra & Avasthy (1988)		Sugarcane	
				David *et al.* (1989)		Sugarcane	
				Jaipal & Chaudhary (1994)		Sugarcane	
				Rai *et al.* (1999)		Sugarcane	
			Indonesia	Mohyuddin (1986)		Sugarcane	
	Trichogrammatidae	*Trichogramma* spp.	Indonesia	Tan & koh (1980)	E	Sugarcane	
	"	*Trichogramma chilonis* Ishii	India	Singhal *et al.* (2001)	E	Sugarcane	Mass released.
			Indonesia	Mohyuddin (1986)		Sugarcane	Mass released.
			Taiwan	Cheng *et al.* (1987b)		Sugarcane	
			China	Liu *et al.* (1996)		Sugarcane	
	"	*Trichogramma japonicum* Ashm.	Taiwan	Box (1953)	E	Sugarcane	
	"	*Trichogramma nanum* Zhnt.	Malaysia	Box (1953)	E	Sugarcane	
			Predators				
	Forficulidae	*Forficula* sp.	India	Butani (1972)	L	Sugarcane	
***Chilo infuscatellus* Snellen**							
Parasitoids							
	Bethylidae	*Goniozus* (*cuttackensis* Lal) *indicus* Ashmead	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
				Butani (1972)		Sugarcane	
	"	*Goniozus* sp.	Philippines	Box (1953)	L	Sugarcane	
			Taiwan	Cheng (1986)		Sugarcane	
				Cheng *et al.* (1987b)		Sugarcane	
				Butani (1972)		Sugarcane	
	Braconidae	*Allorhogas pyralophagus* Marsh	India	Shenhmar *et al.* (1990)	L	Sugarcane	Introduced from Mexico, long term impact on pest unclear.
	"	*Apanteles phytometrae* Wilkinson	India	Butani (1972)	?	Sugarcane	
	"	*Bracon chinensis* Szepligetti	India	Box (1953)	L	Sugarcane	
			Taiwan	Box (1953)		Sugarcane	
			Philippines	Box (1953)		Sugarcane	
		Bracon chinensis (*Amyosoma, Microbracon*) (*albolineatus* Cameron, *chilonis* Viereck)	India	Butani (1972)	L	Sugarcane	
	"	*Campyloneurus mutator* Fabricius	India	Butani (1972)	L	Sugarcane	
	"	*Chelonus munakatae*	China	Li (1985b)	L	Millet	
		Cotesia (*Apanteles*) *flavipes*	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
				Butani (1972)		Sugarcane	
				Nagarkatti & Nair (1973)		Vetiver	

					grass"	
			Srikanth *et al.* (1999)		Sugarcane	
		Pakistan	Mohyuddin (1991)		Sugarcane	A"sugar-cane" adapted strain is well established*.
		Philippines	Box (1953)		Sugarcane	
		Taiwan	Cheng *et al.* (1987a)		Sugarcane	
		Thailand	Suasa-ard & Charernsom (1995)		Sugarcane	
"	*Macrocentrus jacobsoni* Szépl.	Taiwan	Box (1953)	L	Sugarcane	
"	*Microbracon chinensis*	Taiwan	Cheng *et al.* (1999b)	L	Sugarcane	
"	*Stenobracon deesae* Cameron	India	Box (1953)	L	Sugarcane	
			Butani (1958)		Sugarcane	
		Pakistan	Carl (1962)		Sugarcane	Low parasitism levels recorded (5.1%).
"	*Stenobracon nicevillei* Bingham	India	Butani (1972)	L	Sugarcane	Possibly a synonym of *S. maculata* Vier., a rice stemborer parasitoid in Taiwan.
"	*Stenobracon trifasciatus* Szépl.	Taiwan	Box (1953)	L	Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
"	*Tropobracon* (*Shirakia*) *schoenobii* (Viereck)	India	Butani (1972)	?	Sugarcane	
"	*Vipio* (*Stenobracon, Bracon, Glyptomorpha*) *deesae* (Cameron)	India	Butani (1972)	L	Sugarcane	
Chloropidae	*Mepachymerus* (*Stellocerus*) *tenellus* Becker	India	Butani (1972)	?	Sugarcane	
Empididae	*Drapetis* sp.	India	Butani (1972)	L	Sugarcane	
Eulophidae	*Aprostocetus* sp.	India	Butani (1958)	P	Sugarcane	
		India	Butani (1972)		Sugarcane	
"	*Tetrastichus ayyari* Rohwer	India	Butani (1958)	P	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Tetrastichus israeli* Mani & Kurian (*Aprostocetus israeli* Mani)	India	Butani (1972)	P	Sugarcane	
"	*Tetrastichus schoenobii* Ferriere	India	Butani (1972)	E	Sugarcane	
"	*Tetrastichus* sp.	India	Butani (1958)	?	Sugarcane	
			Butani (1972)	P	Sugarcane	
Ichneumonidae	*Brachycoryphus nersei* Cameron	India	Butani (1972)	L, P	Sugarcane	
"	*Centeterus alternecaloratus* Cushman	India	Butani (1972)	P	Sugarcane	
"	*Gotra marginata* Brulle (*Listrognathus marginatus* WLK)	India	Butani (1958)	L?	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Horogenes lineata* Ishida	Taiwan	Box (1953)	?	Sugarcane	

" *Vetiveria zizamoides*

* Mohyuddin (1992) states that a number of *C. flavipes* sugar-cane adapted strains were imported from Indonesia, Thailand and Barbados and crossed, bred freely among themselves and relaesd in Pakistan in 1983 and in the Punjab in 1982-1985. This resulted in successful establishment in sugarcane.

"	*Isotima* sp.	Pakistan	Carl (1962)	L	Sugarcane	
		Philippines	Alba (1989)		Sugarcane	
"	*Melcha ornatipennis* Cameron	India	Butani (1958)	P	Sugarcane	
"	*Meloboris sinicus* (Holmgren)	Taiwan	Cheng *et al.* (1987b)	L	Sugarcane	
			Cheng *et al.* (1999a)		Sugarcane	
"	*Xanthopimpla* (*Pimpla*) *punctata* Fabricus	India	Butani (1972)	P	Sugarcane	
"	*Xanthopimpla stemmator* Thunberg	Taiwan	Sonan (1929)	P	Sugarcane	
			Cheng *et al.* (1987b)		Sugarcane	
	Xanthopimpla (Ichneumon) stemmator Thunberg (*thoracalis* Krieger, *bimaculata* Cameron, *maculifrons* Cameron, *nursei* Cameron, *fascialis* Szepligetti, *Habropimpla sesamiae* Rao*)*	India	Butani (1972)	P	Sugarcane	
Scelionidae	*Telenomus* sp.	India	Butani (1972)	E	Sugarcane	
	Telenomus alecto Crawford	India	Butani (1972)	E	Sugarcane	Introduced from Colombia, well established in West Bengal.
	Telenomus (*Ceraphron*, *Phanurus*, *Praphanurus*) *beneficiens* (Zehntner) Nixon	India	Butani (1958)	E	Sugarcane	
"	*Telenomus* (*Phanurus*, *Praphanurus*) *beneficiens* (Zehntner) (Ceraphron)	India	Butani (1972)	E	Sugarcane	
		Taiwan	Box (1953)		Sugarcane	
"	*Telenomus dignoides* Nixon	India	Butani (1972)	E	Sugarcane	
"	*Telenomus rowani* (Gahan)	Thailand	Suasa-ard & Charernsom (1995)	E	Sugarcane	
Tachinidae	*Exorista quadrimaculata* Baranov	India	Butani (1972)	L	Sugarcane	
"	*Lixophaga diatrae*(*diatraeae*)	Philippines	Alba (1990)	L	Sugarcane	Introduced into the Philippines from South America, resulted in low parasitism levels.
"	*Sturmiopsis inferens* Townsend	India	Butani (1972)	L	Sugarcane	
			Pawar (1987)		Sugarcane	
			David *et al.* (1989)		Sugarcane	
			Easwaramoorthy *et al.* (1999)		Sugarcane	
“	*Sturmiopsis* (*Winthemia*) *semiberbis* Bezzi	India	Butani (1958)	L	Sugarcane	
Trichogrammatidae	*Trichogramma australicum* Girault	India	Butani (1972)	E	Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
		Taiwan	Box (1953)		Sugarcane	
		Pakistan	Hashmi & Rahim (1985)		Sugarcane	
"	*Trichogramma bactrea* Nagaraja	India	David & Easwaramoorthy (1990)	E	Sugarcane	
"	*Trichogramma chilonis* Ishii	China	Liu *et al.* (1996)	E	Sugarcane	
		India	Tuhan & Pawar (1983)		Sugarcane	A strain from Taiwan is mass released in India.

				David & Easwaramoorthy (1990)		Sugarcane	Widely mass releasd in India.*
			Indonesia	Mohyuddin (1992)		Sugarcane	Augmentative releases early in the season increased parasitism rates to almost 98%.
			Pakistan	Mohyuddin (1991)		Sugarcane	Mass released.
				Ashraf & Fatima (1996)		Sugarcane	Mass released.
			Philippines	Alba (1990)		Sugarcane	
				Javier & Gonzalez (2000)		Sugarcane	
			Taiwan	Cheng *et al.* (1987b)		Sugarcane	
	"	*Trichogramma chilotraeae* Nagaraja and Nagarkatii	Philippines	Alba (1990)	E	Sugarcane	
			Thailand	Meenakanit *et al.* (1988)		Sugarcane	
				Suasa-ard & Charernsom (1995)		Sugarcane	
			India	David & Easwaramoorthy (1990)		Sugarcane	
	"	*Trichogramma confusum* (*T. chilonis*)	China	Liu *et al.* (1985)	E	Sugarcane	Mass released.
				Dai *et al.* (1988)		Sugarcane	Mass released.
	"	*Trichogramma evanescens minutum* Riley	India	Butani (1958)	E	Sugarcane	
	"	*Trichogramma flandersi* Nagaraja & Nagarkatti	India	David & Easwaramoorthy (1990)	E	Sugarcane	
	"	*Trichogramma japonicum* Ashmead	India	Butani (1972)	E	Sugarcane	
	"	*Trichogramma minutum* Riley	India	Box (1953)	E	Sugarcane	
	"	*Trichogramma nagarkattii*	China	Guo (1988)	E	Sugarcane	Mass released.
	"	*Trichogramma nanum* Zhnt.	India	Box (1953)	E	Sugarcane	
			Indonesia	Box (1953)		Sugarcane	
			Philippines	Alba (1990)		Sugarcane	
	"	*Trichogramma nubilale*	China	Guo (1988)	E	Sugarcane	Mass released.
	"	*Trichogramma plasseyensis* Nagaraja	India	David & Easwaramoorthy (1990)	E	Sugarcane	
	"	*Trichogramma poliae* Nagaraja	India	David & Easwaramoorthy (1990)	E	Sugarcane	
	"	*Trichogramma semblidis* (Auriv.)	India	David & Easwaramoorthy (1990)	E	Sugarcane	
	"	*Trichogrammatoidea nana* Zehntner	India	Butani (1958)	E	Sugarcane	
				Butani (1972)		Sugarcane	
	"	*Trichogramma* sp.	Philippines	Alba (1991)	E	Sugarcane	
Predators							
	Lycosidae	*Hippasa greenalliae* (Blackwell)	India	Easwaramoorthy *et al.* (1996b)	L	Sugarcane	
Pathogens							
	Hypomycetes	*Beauveria* nr. *bassiana*	India	Sivasankaran *et al.* (1990)	L	Sugarcane	
	Mermithidae	*Amphimermis* sp.	Pakistan	Carl (1962)	L	Sugarcane	
	Nosematidae	*Nosema infuscatellus*	China	Wen & Sun (1989)	L	Sugarcane	
		Granulosis virus (GV)	India	Easwaramoorthy & Jayaraj (1987)	L	Sugarcane	
***Chilo partellus* (Swinhoe)**							
Parasitoids							

* David and Easwaramoorthy (1992) state that *T. chilonis* was formerly misidentified in India as *Trichogramma evanescens minutum*, *Trichogramma australicum* and *Trichogramma confusum*.

Bethylidae	*Goniozus indicus* Muesebeck	India	Kurian (1952)	L	Rice	
"	*Goniozus* (*cuttackensis* Lal) *indicus* Ashmead	India	Butani (1958)	L	Sugarcane	
			Butani (1972)	L	Sugarcane	
		Philippines	Nickel (1964)		Rice	
"	*Goniozus* sp.	Pakistan	CIBC (1966)	?	Maize	
Braconidae	*Allorhogas pyralophagus* Marsh	India	Varma & Saxena (1989)	L	Sorghum	Introduced from Mexico, established[*].
"	*Apanteles* sp.	India	Devi & Raj (1996)	L	Maize	
"	*Apanteles chilonis*(Munakata)	India	Sharma *et al.* (1966)	L	?	
"	*Apanteles schoenobii* Wilkinson	India	Butani (1972)	L	Sugarcane	
"	*Bracon albolineatus* Cam.	India	Kishore (1986)		Sorghum	First record in India.
"	*Bracon chinensis* Szépligeti	Pakistan	Carl (1962)	L	Maize	
		India	Box (1953)		Sugarcane	
			Butani (1958)		Sugarcane	
			Butani (1972)		Sugarcane	
		Nepal	Neupane *et al.* (1985)		Maize	
		Sri Lanka	Box (1953)		Sugarcane	
	Cotesia (*Apanteles*) *flavipes* Cameron	Pakistan	Alam *et al.* (1972)	L	Maize & sorghum	A Japanese strain was introduced in 1962, well established.
			Mohyuddin (1990)		Maize	
			Mohyuddin (1991)		Sugarcane["]	
		India	Box (1953)		Sugarcane	
			Butani (1958)		Sugarcane	
			Subba Rao *et al.* (1969)		Maize & sorghum	
			Butani (1972)		Sugarcane	
			Nagarkatti & Nair (1973)		Sorghum & wild cane[#]	
			Singh *et al.* (1975)		Maize	
			Kishore (1986)		Sorghum	
			Nair (1988)		Job's tears[♣]	
			Srikanth *et al.* (1999)		Sorghum	
		Nepal	Neupane *et al.* (1985)		Maize	
		Comoros	Brenière *et al.* (1985)		Maize	
		Sri Lanka	Box (1953)		Sugarcane	
		Taiwan	Box (1953)		Sugarcane	
"	*Chelonus heliopae* Gupta	India	Butani (1972)	L	Sugarcane	

[*] A more recent study by Easwaramoorthy et al (1992) failed to recover *Allorhogas pyralophagus* from canefields after release. Impact of parasitoid seems minimal.

["] A hybrid between a sugarcane-adapted strain, from Indonesia, and a local maize-adapted strain was established in sugarcane plantations in the Sind Province of Pakistan (Mohyuddin (1991).

[#] *Saccharum spontaneum*

[♣] *Coix lachryma-jobi* L.

"	*Chelonus* sp. (b)	Pakistan	Carl (1962)	?	Maize	
"	*Iphiaulax spilocephalus* Cameron	India	Butani (1958)	L	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Merinotus* sp.	India	Butani (1972)	?	Sugarcane	
"	*Microbracon chilocida* Ram.	India	Butani (1972)	?	Sugarcane	
"	*Microplitis* sp.	India	Butani (1972)	?	Sugarcane	
"	*Rhaconotus scirpophagae* Wilkinson	India	Butani (1958)	L	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Stenobracon deesae* (Cameron)	Pakistan	Carl (1962)	L	Maize	
		India	Box (1953)		Sugarcane	
			Butani (1957)		Sugarcane	
			Butani (1958)		Sugarcane	
"	*Stenobracon nicevillei* (Bingham)	India	Butani (1957	L	Sugarcane	
			Butani (1958)		Sugarcane	
			Butani (1972)		Sugarcane	
		Nepal	Neupane *et al.* (1985)		Rice, maize & sorghum	
"	*Tropobracon* (*Shirakia*) *schoenobii* (Viereck)	India	Butani (1972)	?	Sugarcane	
"	*Vipio* (*Stenobracon, Bracon, Glyptomorpha*) *deesae* (Cameron)	India	Butani (1972)	L?	Sugarcane	
"	*Vipio* sp.	India	Butani (1972)	L	Sugarcane	
Chalcididae	*Hyperchalcidia* sp.	Pakistan	Carl (1962)	P	Maize	
"	*Hyperchalcidia soudanensis* Steffan	Nepal	Neupane *et al.* (1985)	P	Rice, maize & sorghum	
Eulophidae	*Aprostocetus* sp.	India	Butani (1972)	P	Sugarcane	
"	*Pediobius furvus* (Gahan)	Comoros	Brenière *et al.* (1985)	P	Maize	Introduced from Madagascar in 1969-1971.
		Madagascar	Betbeder-Matibet (1989)		Sorghum	Introduced into Madagascar from Uganda in 1968, well *established.*
"	***Tetrastichus*** ayyari Rohwer	India	Butani (1958)	P	Sugarcane	
			Butani (1972)		Sugarcane	
		Reunion	Betbeder-Matibet (1989)		Sorghum	
Ichneumonidae	*Centeterus alternecaloratus* Cushman?	India	Chacko & Rao (1966)	P	Maize	Recorded as a key pupal parasitoid in India, with up to 50% parasitism levels.
	Centeterus alternecaloratus Cushman	India	Butani (1972)	P	Maize	
"	*Cremastus flavo-orbitalis* Cam.	Sri Lanka	Box (1953)	?	Sugarcane	
“	*Trathala flavoorbitalis* Cameron	Nepal	Neupane *et al.* (1985)	L	Rice, maize & sorghum	
"	*Xanthopimpla punctator* (*predator* Fabricius) Linnaeus	India	Butani (1972)	P	Sugarcane	
"	***Xanthopimpla stemmator*** Thunberg	India	Box (1953)	P	Sugarcane	

			Sri Lanka	Box (1953)		Sugarcane	
			Nepal	Neupane *et al.* (1985)		Rice, maize & sorghum	
		Xanthopimpla (Ichneumon) stemmator Thunberg (*thoracalis* Krieger, *bimaculata* Cameron, *maculifrons* Cameron, *nursei* Cameron, *fascialis* Szepligetti, ***Habropimpla sesamiae*** (Rao)	India	Butani (1972)	P	Sugarcane	
“		***Xanthopimpla stemmator*** Timberlake	Pakistan	Carl (1962)	P	Maize	
			Sri Lanka	Vinson (1942)*		Maize	
			India	Butani (1958)		Sugarcane	
				Neupane (1990)		Rice, maize & sorghum	
			Taiwan	Box (1953)		Sugarcane	
	“	*Xanthopimpla predator* Fabricius	India	Butani (1958)	P	Sugarcane	
	“	*Xanthopimpla nursei* Cameron	India	Butani (1958)	P	Sugarcane	
	Phoridae	Phorid fly	India	Butani (1972)	?	Sugarcane	
	Tachinidae	*Sturmiopsis inferens* Townsend	India	Butani (1972)	L	Sugarcane	
	"	*Sturmiopsis* (*Winthemia*) *semiberbis* Bezzi	India	Butani (1958)	L	Sugarcane	
	Trichogrammatidae	*Trichogramma chilonis* Ishii	India	Tuhan & Pawar (1983)	E	Sugarcane	Mass released.
				Chundurwar (1989)		Sorghum	
			Nepal	Neupane *et al.* (1985)		Rice, maize & sorghum	
				David & Easwaramoorthy (1990)		Sugarcane	
	"	*Trichogramma evanescens minutum* Riley	India	Butani (1958)	E	Sugarcane	
	"	*Trichogramma exiguum*	India	Jotwani (1982)	E	Sorghum	
				Chundurwar (1989)	E	Sorghum	Different strains introduced from Barbados, Colombia and the Philippines, well established in Delhi and Nagpur.
Predators							
	Coccinellidae	*Menochilus sexmaculatus* (Fabricius)	India	Jotwani & Verma (1969)	L	Sorghum	
	Reduviidae	*Acanthaspis quinquespinosa* Fabricius	India	Butani (1958)	L	Sugarcane	
				Butani (1972)	L	Sugarcane	
	Staphylinidae	*Paederus fucipes* Curtis	Pakistan	Mohyuddin *et al.* (1972)	E	Maize	
Pathogens							
	Bacillaceae	*Bacillus thuringiensis* Berliner	India	Sukhani (1986)	L	Sorghum	
	Hyphomycetes	*Beauveria densa*	India	Sukhani (1986)	L	Sorghum	
	Mermithidae	*Hexamermis* sp.	India	Sukhani (1986)	L	Sorghum	
	Protozoa	*Tetrahymena* sp.	India	Sukhani (1986)	L	Sorghum	
	Rhabditida	*Rhabditis* sp.	India	Sukhani (1986)	L	Sorghum	
	"	*Panagrolaimus* sp.	India	Sukhani (1986)	L	Sorghum	
	Steinernematidae	*Neoaplectana* sp.	India	Sukhani (1986)	L	Sorghum	

* Apparently a misidentification of the host (*C. partellus*) (See Greathead 1971).

Chilo polychrysus Meyrick

Parasitoids							
	Braconidae	*Apanteles flavipes* Cam.	Malaysia	Kalshoven (1981)	L	Rice	
"		*Apanteles flavipes* (*nonagriae*) Cam.	Australia (NT)	Li (1970)	L	Rice	
	Chalcididae	*Euchalcidia* sp.	Australia (NT)	Li (1970)	P	Rice	
	Tachinidae	*Dichaetomyia pallitarsus* (Stein)	Malaysia	Kalshoven (1981)	P	Rice	
	"	*Sturmiopsis inferens* Towns.	Malaysia	Kalshoven (1981)	P	Rice	
	Trichogrammatidae	*Trichogramma* sp.	Malaysia	Kalshoven (1981)	E	Rice	
	Scelionidae	*Telenomus* sp.	Malaysia	Kalshoven (1981)	E	Rice	
	Mymaridae	*Anagrus* sp.	Malaysia	Kalshoven (1981)	E	Rice	
***Chilo sacchariphagus* (Bojer)**							
Parasitoids							
	Bethylidae	*Goniozus indicus* Ashmead	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
		Goniozus indicus Ashmead (= *cuttackensis* L)	India	Butani (1972)	L	Sugarcane	
	Braconidae	*Agathis stigmatera* (Brullé) (*Alabagrus stigma* Cresson)	Mauritius	Greathead (1971)	L	Sugarcane	Introduced from Trinidad (1949-1951).
				Facknath (1989)		Sugarcane	
				Ganeshan & Rajabalee (1997)		Sugarcane	Low levels of Parasitism recorded.
				Ganeshan (2000)		Sugarcane	
	"	*Allorhogas pyralophagus* Marsh	Mauritius	Facknath (1989)	L	Sugarcane	Originally from Mixeco, introduced into Mauritius but apparently unsuccessful.
	"	*Apanteles* sp.	Indonesia	Tan & Koh (1980)	L	Sugarcane	
	"	*Bracon chinensis* Szepl.	Mauritius	Greathead (1971)	L	Sugarcane	Introduced from Srilanka in 1939.
	"	*Camphyloneurus* sp.	Indonesia	Tan & Koh (1980)	L	Sugarcane	
	"	*Campyloneurus erythrothorax* Szépl.	Indonesia	Kalshoven (1981)	L	Sugarcane	
	"	*Cotesia* (*Apanteles*) *flavipes* Cameron	Mauritius	Box (1953)	L	Sugarcane	
				Moutia & Courtois (1952)		Sugarcane	
				Greathead (1971)		Sugarcane	Originally from India, Well established[*].
				Williams (1978)		Sugarcane	
				Williams (1983)		Sugarcane	

[*] Greathead (1971) states that, in 1964, a shipment of *Apanteles* sp. (possibly *Cotesia flavipes*) arrived in Mauritius from India, while Appert (1973) states that *Cotesia flavipes* was introduced into Mauritius in 1917, and then later into the Reunion. It is also possible that *C. flavipes* may have arrived with it's host around 1850 from India (see Greathead 1971; Mohyuddin 1971; Overholt 1998).

			Rajabalee & Governdasamy (1988)		Sugarcane	
			Facknath (1989)		Sugarcane	
			Ganeshan & Rajabalee (1997)		Sugarcane	
			Ganeshan (2000)		Sugarcane	
		Madagascar	Betbeder-Matibet & Malinge (1968)		Sugarcane	
			Appert *et al.* (1969)		Sugarcane	Introduced from Mauritius in 1960-1961, well established.
		Reunion	Greathead (1971)		Sugarcane	
		Taiwan	Box (1953)		Sugarcane	
			Cheng *et al.* (1987a)		Sugarcane	
		Thailand	Suasa-ard & Charernsom (1995)		Sugarcane	
		Indonesia	Kalshoven (1981)		Sugarcane	
			Sunaryo and Suryanto (1986)		Sugarcane	
			Mohyuddin (1986)		Sugarcane	An imported Thai strain in 1985 improved overall parasitism rates.
		India	Box (1953)		Sugarcane	
			Butani (1958)		Sugarcane	
			Butani (1972)		Sugarcane	
			Easwaramoorthy & Nandagopal (1986)		Sugarcane	
			Easwaramoorthy *et al.* (1992)		Sugarcane	
			Srikanth *et al.* (1999)		Sugarcane	
"	*Hormiopterus* (*Rhaconotus*) sp.	Indonesia	Kalshoven (1981)	L	Sugarcane	
"	*Microbracon chinensis*	Taiwan	Cheng *et al.* (1987b)	L	Sugarcane	
"	*Macrocentrus jacobsoni* Szépl.	Taiwan	Box (1953)	?	Sugarcane	
"	*Rhaconotus roslinensis* Lal (*caulicola* Muesebeck)	India	Butani (1958)	L	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Rhaconotus signipennis* Walker	India	Butani (1972)	L	Sugarcane	
"	*Stenobracon deesae*	India	Easwaramoorthy *et al.* (1992)	L	Sugarcane	
Chalcididae	*Trichospilus diatraea* Chairman & Margabandhu	India	Butani (1972)	P	Sugarcane	
		Mauritius	Facknath (1989)		Sugarcane	
			Greathead (1971)		Sugarcane	Introduced from India in (1959, established.
			Williams (1978)		Sugarcane	
			Ganeshan (2000)		Sugarcane	
		India	Box (1953)		Sugarcane	
			Butani (1958)		Sugarcane	
Eulophidae	*Tetrastichus atriclavus* Waterst	Mauritius	Ganeshan & Rajabalee (1997)	P	Sugarcane	Introduced into Mauritius, low levels of parasitism recorded.
			Facknath (1989)	P	Sugarcane	

"	***Tetrastichus ayyari*** Rohwer	India	Butani (1958)	P	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Tetrastichus* sp.	India	Butani (1958)	P	Sugarcane	
			Butani (1972)		Sugarcane	
			Easwaramoorthy & Nandagopal (1986)		Sugarcane	
"	*Tetrastichus* sp. (near *atriclavus* Waterst.)	Mauritius	Box (1953)	P	Sugarcane	
			Moutia & Courtois (1952)		Sugarcane	
			Ganeshan & Rajabalee (1997)		Sugarcane	
Ichneumonidae	*Amauromorpha schoenobii* Vier.	Indonesia	Box (1953)	?	Sugarcane	
"	*Enicospilus antankarus* Sauss.	Mauritius	Box (1953)	?	Sugarcane	
"	*Gambroides* sp.	Indonesia	Tan & Koh (1980)	P	Sugarcane	
"	*Gambroides rufithorax* Uchida	Taiwan	Box (1953)	?	Sugarcane	
	Goryphus sp.	India	Butani (1972)	L?	Sugarcane	
"	*Goryphus* (*Melcha*) *ornatipennis* Cameron	India	Butani (1972)	?	Sugarcane	
"	*Goryphus basilaris* Holmgren (*Exetastes*, *Mesosternus longicornis* Ishida)	India	Butni (1972)	?	Sugarcane	
"	*Mesostenus longicornis* Ishida	India	Box (1953)		Sugarcane	
"	*Meloboris sinicus*	Taiwan	Cheng *et al.* (1987b)	L	Sugarcane	
			Cheng *et al.* (1999a)		Sugarcane	
"	*Xanthopimpla citrina* (*X. luteola*) (Hlmgr.)	Mauritius	Moutia & Courtois (1952)	P	Sugarcane	
			Facknath (1989)		Sugarcane	
			Box (1953)		Sugarcane	
	Xanthopimpla sp.	Indonesia	Tan & Koh (1980)	P	Sugarcane	
"	*Xanthopimpla stemmator* Thunb.	Mauritius	Greathead (1971)	P	Sugarcane	Introduced from Sri Lanka (1939-1942) and few individual released. Well established.
			Moutia & Courtois (1952)		Sugarcane	
			Williams (1978)		Sugarcane	
			Facknath (1989)		Sugarcane	
			Ganeshan (2000)		Sugarcane	
		India	Ganeshan & Rajabalee (1997)		Sugarcane	
		Indonesia	Kalshoven (1981)		Sugarcane	
		Reunion	Caresche (1962)		Sugarcane	
			Greathead (1971)		Sugarcane	Introduced from Mauritius in 1953, 1966.
		Taiwan	Box (1953)			Sugarcane
	Xanthopimpla (Ichneumon) stemmator Thunberg *(thoracalis* Krieger*, bimaculata* Cameron*, maculifrons* Cameron, *nursei* Cameron, *fascialis* Szepligetti, *Habropimpla sesamiae* Rao)	India	Butani (1972)	P	Sugarcane	
Scelionidae	*Telenomus sp.*	Indonesia	Kalshoven (1981)	E	Sugarcane	High parasitism levels recorded (90%).

			Tan & Koh (1980)		Sugarcane	
"	*Telenomus beneficiens* Nixon	India	Butani (1958)	E	Sugarcane	
			Butani (1972)		Sugarcane	
			Easwaramoorthy *et al.* (1983)		Sugarcane	
			Rajendran & Gobalan (1995)		Sugarcane	
			Rajendran (1999)		Sugarcane	
"	*Telenomus beneficiens* (Zehnt.)	India	Easwaramoorthy & Nandagopal (1986)	E	Sugarcane	
"	*Telenomus beneficiens* (Zehntner) (Ceraphron)	Mauritius	Box (1953)	E	Sugarcane	
		Taiwan	Box (1953)		Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
		China	Cheng *et al.* (1997)		Sugarcane	
"	*Telenomus dignoides* Nixon	India	Easwaramoorthy *et al.* (1983)	E	Sugarcane	
			Easwaramoorthy & Nandagopal (1986)		Sugarcane	
"	*Telenomus globosus* n. sp.	India	Bin & Johnson (1982)	E	Sugarcane	
			Easwaramoorthy & Nandagopal (1986)		Sugarcane	
"	*Telenomus rowani* (Gahan)	Thailand	Suasa-ard & Charernsom (1995)	E	Sugarcane	
Tachinidae	*Carcelia* sp.	Indonesia	Kalshoven (1981)	L	Sugarcane	
"	*Diatraeophaga* sp.	Indonesia	Kalshoven (1981)	P	Sugarcane	Mass released.
	Diatraeophaga striatalis Tns.	Indonesia	Box (1953)	P	Sugarcane	
		India	David & Easwaramoorthy (1990)		Sugarcane	Imported from Java and released in Tamil Nadu, India, in 1979, later recovered from release sites.
"	*Schistochilus aristatum* Aldr.	Indonesia	Box (1953)	?	Sugarcane	
"	*Sturmiopsis inferens* Townsend	Indonesia	Mohyuddin (1986)	L	Sugarcane	Mass released.
Trichogrammatidae	*Trichogramma australicum* Girault	Mauritius	Box (1953)	E	Sugarcane	
			Greathead (1971)		Sugarcane	Introduced from India in (1964, well established.
			Facknath (1989)		Sugarcane	
			Ganeshan & Rajabalee (1997)		Sugarcane	
			Ganeshan (2000)		Sugarcane	
"	*Trichogramma* sp. (? *australicum* Girault)	Mauritius	Moutia & Courtois (1952)	E	Sugarcane	
"	*Trichogramma bactrea* Nagaraja	India	David & Easwaramoorthy (1990)	E	Sugarcane	
"	*Trichogramma chilonis* Ishii	India	Easwaramoorthy *et al.* (1983)	E	Sugarcane	
			Easwaramoorthy & Nandagopal (1986)		Sugarcane	
			Selvaraj *et al.* (1994)		Sugarcane	
			Rajendran & Gobalan (1995)		Sugarcane	Mass released.
			Rajendran & Hanifa (1996)		Sugarcane	
			Rajendran & Hanifa (1997)		Sugarcane	
			Rajendran & Hanifa (1998)		Sugarcane	
		Taiwan	Cheng (1986)		Sugarcane	

				Cheng *et al.* (1987b)		Sugarcane	
			Reunion	Goebel *et al.* (2000)		Sugarcane	
	"	*Trichogramma chilotraeae* Nagaraja & Nagarkatti	Thailand	Suasa-ard & Charernson (1995)	E	Sugarcane	
	"	*Trichogramma confusum* (*T. chilonis*)	China	Dai *et al.* (1988)	E	Sugarcane	
				Lin *et al.* (1985)		Sugarcane	Mass released.
	"	*Trichogramma evanescens minutum* Riley	India	Butani (1958)	E	Sugarcane	
	"	*Trichogramma* nr. *nana* (Zehnt.)	Indonesia	Kalshoven (1981)	E	Sugarcane	
			Madagascar	Box (1953)		Sugarcane	
			Taiwan	Box (1953)		Sugarcane	
	"	*Trichogramma nanum* Zhnt.	Taiwan	Box (1953)	E	Sugarcane	
	"	*Trichogramma nubilale* Ertle & Davis	China	Liu *et al.* (1987)	E	Sugarcane	Introduced from USA into China in 1983. Mass released.
Predators							
	Carabidae	*Hexagonia* sp? *Insignis* (Bates)	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	Chrysopidae	*Chrysopa* sp.	Indonesia	Kalshoven (1981)	E	Sugarcane	
	Formicidae	*Anoplolepis longipes* Jerdon	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Camponotus compressus* (F.)	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Camponotus rufogloucus* (Jerdon)	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Monomorium aberrans* Forel	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Oecophylla amaragdina* Fabr.	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Pheidole megacephala* Fab.	Reunion	Goebel *et al.* (2000)	E	Sugarcane	
			Mauritius	Williams (1978)	?	Sugarcane	
	"	*Pheldiogeton* sp.	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Solinopsis geminala* (F.)	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	"	*Tetraponera refonigra* Jerdon	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	Glubionidae	*Oedignatha* sp.	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	Lycosidae	*Paradosa* sp.	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	Oxyopidae	*Oxyopes* sp.	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	Salticidae	*Carrhotus viduus* Koch	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
		Plexippus paykulli (Audouin)	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	
	Thomisidae	*Runcinia* sp.	India	Easwaramoorthy & Nandagopal (1986)	E,(L?)	Sugarcane	

Pathogens							
	Hyphomycetes	*Hirsutella nodulosa* Petch	India	Easwaramoorthy *et al.* (1996a)	L	Sugarcane	
				Easwaramoorthy *et al.* (1998)		Sugarcane	
	"	*Metarhizium anisopliae*(Metschnikoff)	Mauritius	Ganeshan (2000)	L	Sugarcane	
	"	*Paecilomyces* sp.	Mauritius	Ganeshan (2000)	L	Sugarcane	
	Mermithidae	*Mermis* sp.	Mauritius	Moutia & Courtois (1952)	L	Sugarcane	
	Nosematidae	*Nosema furnacalis*	China	Wen & Sun (1988)	?	?	
		Granulosis virus	India	Mehta & David (1980)	L	Sugarcane	
				Easwaramoorthy & Nandagopal (1986)		Sugarcane	
				Easwaramoorthy & Jayaraj (1987)		Sugarcane	
***Chilo suppressalis* (Walker)**							
Parasitoids							
	Braconidae	*Apanteles flavipes* Cam. (*A. nonagriae* Oll.)	Australia (NT)	Li (1970)	L	Rice	
	"	*Apanteles chilonis*(Munakata)	Japan	Kajita & Drake (1969)	L	Rice	
				Imamura & Yamazaki (1975)		Rice	
				Imamura & Machimura (1976)		Rice	
	"	*Bracon chinensis* Szépl.	Indonesia	Kalshoven (1981)	L	Rice	
	"	*Cotesia flavipes* Cameron	Japan	Kajita & Drake (1969)	L	Rice	
			Taiwan	Cheng *et al.* (1987a)		Sugarcane*	
	Eulophidae	*Tetrastichus israeli* (M.&K.)	Indonesia	Kalshoven (1981)	P	Rice	
	Ichneumonidae	*Xanthopimpla stemmator* Thnb.	Indonesia	Kalshoven (1981)	P	Rice	
	Scelionidae	*Telenomus dignus* Gah.	Indonesia	Kalshoven (1981)	E	Rice	
	Tachinidae	*Sturmiopsis inferens* Towns	Malaysia	Kalshoven (1981)	L	Rice	
	Trichogramma	*Trichogramma* sp.	Indonesia	Kalshoven (1981)	E	Rice	Parasitism levels of up to 100% recorded.
Chilo terrenellus Pagenstecher							
Parasitoids							
	Braconidae	*Apanteles flavipes*	PNG	Li (1990)	L	Sugarcane	
	"	*Apanteles* sp.	PNG	Li (1985a)	L	Sugarcane	
				Li (1990)		Sugarcane	
"		*Apanteles* sp. nr *chilonis* Munikata	PNG	Young (1982)	L	Sugarcane	
				Li (1990)		Sugarcane	
	Ceraphronidae	*Ceraphron* sp.	PNG	Li (1990)	L	Sugarcane	
	Scelionidae	*Gryon nixoni* Masner	PNG	Li (1990)	E	Sugarcane	
	"	*Telenomus* sp.	PNG	Young (1982)	E	Sugarcane	
				Li (1990)		Sugarcane	
	Tachinidae	*Carcelia* (*Senametopia*) sp.	PNG	Li (1990)	L	Sugarcane	

* Possibly a misidentification of pest, or pest found occasionally in sugarcane.

	Trichogrammatidae	*Trichogramma* sp.	PNG	Young (1982)	E	Sugarcane	
				Li (1985a)		Sugarcane	
"		*Trichogramma* sp. nr. *plasseyensis* Nagaraja	PNG	Li (1990)	E	Sugarcane	
		Chilo tumidicostalis (Hampson)					
Parasitoids							
	Bethylidae	*Goniozus indicus* Ashmead (*Cuttackensis* Lal)	India	Butani (1972)	L	Sugarcane	
	Braconidae	*Apanteles* sp.	India	Butani (1972)		Sugarcane	
	"	*Campyloneurus mutator* Fabricius	India	Butani (1972)	L	Sugarcane	
	"	*Cotesia flavipes* Cameron	Thailand	Suasa-ard (2000)	L	Sugarcane	
			India	Borah & Sarma (1995)		Sugarcane	
				Borah & Arya (1995)		Sugarcane	
	Eulophidae	Anostocetus sp.	India	Butani (1958)	L	Sugarcane	
				Butani (1972)		Sugarcane	
	Ichneumonidae	*Xanthopimpla* sp.	Thailand	Suasa-ard (2000)	P	Sugarcane	
	Scelionidae	*Telenomus rowani*	Thailand	Suasa-ard (2000)	E	Sugarcane	
	Tachinidae	Unidentified tachinid	Thailand	Suasa-ard (2000)	L	Sugarcane	
	Trichogrammatidae	*Trichogramma chilotraeae*	Thailand	Suasa-ard (2000)	E	Sugarcane	
Family: Noctuidae							
Sesamia calamistis **Hampson**							
Parasitoids							
	Braconidae	*Apanteles* sp.	Reunion	Jacquemard *et al.* (1985)	L	Maize, sugarcane	
	"	*Bracon albolineatus* Cam.	Mauritius	Moutia & Courtois (1952)	?	Rice	Exotic parasitoid, impact on pest unclear.
	"	*Bracon chinensis* Szépl.	Mauritius	Greathead (1971)	L	Sugarcane	Introduced from Sri Lanka in 1939.
				Williams (1978)		Sugarcane	
"		*Cotesia* (*Apanteles*) *sesamiae*	Mauritius	Anon. (1954)	L	Sugarcane	Introduced from Kenya in 1951, well established.
				Greathead (1971)		Maize, sugarcane	
				Williams (1978)		Sugarcane	
				Rajabalee & Governdasamy (1988)		Sugarcane	
				Facknath (1989)		Sugarcane	
				Ganeshan (2000)		Sugarcane	
			Madagascar	Brenière *et al.* (1985)		Maize & sugarcane	Introduced from Uganda, well established.
				Betbeder-Matibet (1989)		Sorghum	
			Reunion	Greathead (1971)		Maize,	Introduced from

						Mauritius in 1953-1955, well established.
			Betbeder-Matibet (1989)		Sorghum	
Eulophidae	*Pediobius furvus* (Gahan)	Madagascar	Greathead (1971)	P	Sugarcane	Introduced from Uganda in 1968, established.
			Appert (1973)		maize & rice	
			Betbeder-Matibet (1989)		Sorghum	
			Mohyuddin (1990)		Maize	
		Comoros	Brenière *et al.* (1985)		Maize	Introduced from Madagascar in 1969-1971, established.
		Reunion	Betbeder-Matibet (1989)		Sorghum	Introduced from Uganda, established.
"	*Tetrastichus* sp. (near *atriclavus* Waterst.)	Mauritius	Moutia & Courtois (1952)	P	Sugarcane	
"	*Tetrastichus israeli* (M. & K.)	Reunion	Betbeder-Matibet (1989)	P	Sorghum	Introduced from India in 1959.
"	*Trichospilus diatraeae* C. & M.	Reunion	Betbeder-Matibet (1989)	P	Sorghum	
		Mauritius	Williams (1978)		Sugarcane	Introduced from India in 1963-1964.
Ichneumonidae	*Enicospilus* sp.	Mauritius	Moutia & Courtois (1952)	L	Sugarcane	
			Box (1953)		Sugarcane	
"	*Ichneumon unicinctus* Brúlle	Mauritius	Williams (1978)	P?	Sugarcane	
"	*Xanthopimpla citrina* (*X. luteola*) (Hlmgr.)	Mauritius	Moutia & Courtois (1952)	P	Sugarcane	Introduced from Sri Lanka in 1952, 1953.
			Box (1953)		Sugarcane	
			Greathead (1971)		Sugarcane	
		Reunion	Greathead (1971)		Sugarcane	Introduced from Mauritius in 1953, 1960.
"	*Xanthopimpla stemmator* (Thunb.)	Mauritius	Moutia & Courtois (1952)	P	Sugarcane & maize	Introduced from Sri Lanka in 1939, well established.
			Greathead (1971)		Sugarcane	
		Reunion	Greathead (1971)		Sugarcane & maize	Introduced from Mauritius in 1953-1960, well established.
Scelionidae	*Platytelenomus* sp. (? *hylas* Nixon)	Mauritius	Moutia & Courtois (1952)	E	Sugarcane	
Trichogrammatidae	*Trichogramma australicum* Gir	Mauritius	Box (1953)	E	Sugarcane	
			Greathead (1971)		Sugarcane	Introduced from India (1964), well established.

	"	*Trichogramma* sp. (1) (? *australicum* Girault)	Mauritius	Moutia & Courtois (1952)	E	Sugarcane	
	"	*Trichogramma* sp. (2) (near *nana* (Zehnt))	Mauritius	Moutia & Courtois (1952)	E	Sugarcane	
			Madagascar	Box (1953)		Sugarcane	
	"	*Trichogramma* sp. (near *nanum* Zhnt.)	Mauritius	Box (1953)	E	Sugarcane	
Pathogens							
	Mermithidae	*Mermis* sp.	Mauritius	Moutia & Courtois (1952)	L	Sugarcane	
		Nuclear polyhedral virus	Reunion	Jacquemard *et al.* (1985)	L	Maize, cane	
		Cytoplasmic polyhedral virus	Reunion	Jacquemard *et al.* (1985)	L	Maize, cane	
	Nodamuraviridae	Unidentified virus	Reunion	Jacquemard *et al.* (1985)	L	Maize, cane	
***Sesamia cretica* Lederer**							
Parasitoids							
	Braconidae	*Habrobracon hebetor* L.	Iran	Shojai *et al.* (1995)	L	Maize	
	Scelionidae	*Platytelenomus busseolae* Gahan	Iran	Shojai *et al.* (1995)	E	Maize	
***Sesamia grisescens* (Warren)**							
Parasitoids							
	Braconidae	*Cotesia flavipes* (Cameron)	PNG	Kuniata & Sweet (1994)	L	Sugarcane	An indigenous population is responsible for high levels of parasitism (up to 70%). Continuously mass released.
				Kuniata (2000)		Sugarcane	
	Eulophidae	*Pediobius furvus* (Gahan)	PNG	Kuniata & Sweet (1994)	P	Sugarcane	Imported from Kenya in 1991. Well established but parasitism level is generally low.
				Kuniata (2000)		Sugarcane	
				Lloyd & Kuniata (2000)		Sugarcane	
	Ichneumonidae	*Enicosphilus* (*Enicospilus*) *terebrus* Gauld	PNG	Kuniata & Sweet (1994)	L	Sugarcane	Levels of parasitism reach up to 14%.
				Kuniata (2000)		Sugarcane	
	Scelionidae	*Telenomus* sp.	PNG	Kuniata & Sweet (1994)	E	Sugarcane	An indigenous strain is used for augmentative releases.
				Kuniata (2000)		Sugarcane	
	Tachinidae	*Carcelia* sp.	PNG	Kuniata & Sweet (1994)	L	Sugarcane	Low levels of parasitism recorded (<4%).
				Lloyd & Kuniata (2000)		Sugarcane	
Predators							

	Anthocoridae	*Blaptostethoides* sp.	PNG	Kuniata & Sweet (1994)	E	Sugarcane
	Chelisochidae	*Chelisoches morio* (F.)	PNG	Kuniata & Sweet (1994)	E,L	Sugarcane
	Formicidae	*Pheidole* sp.	PNG	Kuniata & Sweet (1994)	L, P	Sugarcane
	"	*Irridomymex* spp.	PNG	Kuniata & Sweet (1994)	L, P	Sugarcane
Pathogens						
	Hyphomycetes	*Metarhizium anisopliae*	PNG	Kuniata & Sweet (1994)	L, P	Sugarcane
	"	*Beauveria bassiana*	PNG	Kuniata (1994)	L	Sugarcane
		Unidentified virus	PNG	Kuniata & Sweet (1994)	L	Sugarcane
***Sesamia inferens* (Walker)**						
Parasitoids						
	Bethylidae	*Goniozus indicus* (*cuttackensis* Lal)Ashmead	India	Butani (1972)	L	Sugarcane
	Braconidae	*Apanteles pallipes* Cameron	India	Butani (1972)	L	Sugarcane
	"	*Apanteles ruficrus* Haliday	China	Zhang (1986)	L	Rice
	"	*Bracon brevicornis* Wesmael	India	Butani (1972)	L	Sugarcane
	"	*Bracon chinensis* Szepligetti	India	Butani (1958)	L	Sugarcane
		Bracon (*Amyosoma, Microbracon*) *chinensis* (*albolineatus* Cameron, *chilonis* Viereck)	India	Butani (1972)	L	Sugarcane
			Taiwan	Box (1953)		Sugarcane
			Philippines	Box (1953)		Sugarcane
	"	*Bracon hebetor* Say	India	Butani (1972)	L	Sugarcane
	"	*Cotesia* (*Apanteles*) *flavipes* Cameron	Taiwan	Cheng *et al.* (1987a)	L	Sugarcane
			Japan	Arakaki & Ganaha (1986)		Sugarcane
				Abdul Mannan & Iwahashi (1999)		Sugarcane
				Mia & Iwahashi (1999)		Sugarcane
			India	Kumar & Kalra (1965)		Sugarcane
				Nagarkatti & Nair (1973)		Rice, wild cane"
			Indonesia	Rothschild (1970)		Rice
			Pakistan	Carl (1962)		Cattail*
			Taiwan	Box (1953)		Sugarcane
			Philippines	Box (1953)		Sugarcane
	"	*Iphiaulax* sp.	India	Butani (1972)	L	Sugarcane
	"	*Iphiaulax famulus* Bingham	Philippines	Box (1953)	L	Sugarcane
	"	*Macrocentrus nicevillei* Ashmead	India	Butani (1972)	L	Sugarcane
	"	*Shirakia schoenobii* Vier	Taiwan	Box (1953)	L	Sugarcane
	"	*Tropobracon* (*Shirakia*) *schoenobii* (Viereck)	India	Butani (1972)	?	Rice
	"	*Vipio* sp.	India	Butani (1972)	L	Sugarcane
	Ceraphronidae	*Ceraphron* (*Calliceras*) *fijiensis* Ferriere*	India	Butani (1972)	?	Sugarcane
	Chalcididae	*Brachymeria* (*Chalcis*) sp.	India	Butani (1972)	P	Sugarcane
	Chloropidae	*Anacamptoneurum oblicunum* Becker	India	Butani (1972)	?	Sugarcane
	"	*Anacamptoneurum* sp.	India	Butani (1972)	?	Sugarcane

" *Erianthus arundinaceus*.
* Aquatic weed (*Typha angustata*).
* Possibly a hyperparasitoid on *Cotesia flavipes* (see Chaudhary & Chand (1972).

	"	*Anatrichus erinaceous* Loew	India	Butani (1972)	?	Sugarcane	
	"	*Mepachymerus* (*Stellocerus*) *tenellus* Becker India	India	Butani (1972)	?	Sugarcane	
	Eulophidae	*Tetrastichus ayyari* Rohwer	India	Butani (1958)	P	Sugarcane	
	"			Butani (1972)		Sugarcane	
		Trichospilus diatraea Chairman & Margabandhu	India	Butani (1972)	P	Sugarcane	
	"	*Trichospilus israeli* M&K	Indonesia	Kalshoven (1981)	P	?	
	Ichneumonidae	*Amauromorpha schoenobii* Vier.	Taiwan	Box (1953)	?	Sugarcane	
	"	*Enicospilus sakaguchii* Mats. & Uchida	Taiwan	Box (1953)	?	Sugarcane	
	"	*Habropimpla sesamiae* Rao	India	Butani (1958)	P	Sugarcane	
	"	*Horogenes lineata* Ishida	Taiwan	Box (1953)	?	Sugarcane	
	"	*Nesopimpla naranyae* Ashm.	Taiwan	Box (1953)	?	Sugarcane	
	"	*Metopius sesamiae* Rao	India	Butani (1958)	P	Sugarcane	
	"	*Temelucha* sp.	India	Butani (1972)	L	Rice	
	"	*Vulgichneumon leucaniae*Uchida	China	Li (1981)	P	?	
	"	*Xanthopimpla* (*Metopis*) *sesamiae* (Rao)	India	Butani (1972)	?	Sugarcane	
	"	*Xanthopimpla enderleini* Krieg.	Philippines	Box (1953)	?	Sugarcane	
	"	*Xanthopimpla stemmator* Thunberg	Taiwan	Sonan (1929)	P	Sugarcane	
				Box (1953)		Sugarcane	
	Scelionidae	*Telenomus* sp.	India	Butani (1958)	E	Sugarcane	
	Tachinidae	*Sturmiopsis inferens* Townsend	India	Butani (1972)	L	Sugarcane	
				Easwaramoorthy *et al.* (1991)		Sugarcane	
	"	*Sturmiopsis* (*Winthemia*) *semiberbis* Bezzi	India	Butani (1958)	L	Sugarcane	
	"	*Drino discreta* Van der Wulp	India	Butani (1972)		Sugarcane	
	"	*Pseudoperichaeta orientalis* Wiedmann	India	Butani (1972)	L	Sugarcane	
	Trichogrammatidae	*Trichogramma chilonis* Ishii	China	Liu *et al.* (1996)	E	Sugarcane	Mass released.
Predators							
	Anisolabiidae	*Euborellia stali* Dohn.	Philippines	Barrion *et al.* (1987)	L	Rice	
	Pentatomidae	*Amyotea* (*asopus*) *malabarica* (Fabricius)	India	Pati & Mathur (1986)	L	Rice	
Pathogens							
		Nuclear Polyhedrosis Virus	India	Godse & Nayak (1983)	L	Rice	
			Korea	So & Okada (1989)	L	?	
		Cytoplasmic Polyhedrosis virus	India	Easwaramoorthy *et al.* (1989)	L	?	
		Sesamia uniformis (Dudgeon)					
		Parasitoids					
	Braconidae	*Apanteles flavipes* Cameron	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
			Philippines	Box (1953)		Sugarcane	
		Apanteles (*Cotesia*) *flavipes* Cameron (*nonagriae* Olliff. nec Viereck, *Stenopleura simplicis* Viereck)	India	Butani (1972)	L	sugarcane	
	"	*Bracon chinensis* Szepligetti	Philippines	Box (1953)	L	Sugarcane	
	"	*Iphiaulax famulus* Bingham	Philippines	Box (1953)	?	Sugarcane	
	Ichneumonidae	*Kriegeria heptazonata* Ashm.	Philippines	Box (1953)	?	Sugarcane	
	"	*Xanthopimpla enderleini* Krieg.	Philippines	Box (1953)	?	Sugarcane	
	Trichogrammatidae	*Trichogramma evanescens minutum* Riley	India	Butani (1958)	E	Sugarcane	

Family: Pyralidae

***Acigona steniellus* Hampson**

Parasitoids							
	Braconidae	*Allorhogas pyralophagus* Marsh.	India	Shenhmar *et al.* (1990)	L	Sugarcane	Introduced from Mexico, recorded to have established in release sites.
	"	*Apanteles* (*Cotesia*) *flavipes* Cameron (*nonagriae* Olliff. nec Viereck, *Stenopleura simplicis* Viereck)	India	Butani (1972)	L	Sugarcane	
		Cotesia flavipes Cameron	India	Shenhmar & Brar (1996b)	L	Sugarcane	
				Mohyuddin (1992)		Sugarcane	A sugarcane-adapted Strain was established in the Punjab and in Pakistan.
			Pakistan	Muzaffar & Inayatullah (1986)	L	Sugarcane	
	"	*Rhaconotus roslinensis* Lal (*caulicola* Muesebeck)	India	Butani (1972)	L	Sugarcane	
	"	*Rhaconotus scirpophagae* Wilkinson	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
				Butani (1972)		Sugarcane	
	"	*Rhaconotus signipennis* (Walker)	India	Shenhmar & Varma (1988)	L	Sugarcane	
	"	*Spathius elaboratus* Wilkinson*	India	Saxena (1992)	L	Sugarcane	
	"	*Stenobracon deesae* Cameron	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
		Stenobracon nicevillei Bingham	India	Butani (1972)	L	Sugarcane	
	"	*Vipio* (*Stenobracon, Bracon, Glyptomorpha*) *deesae* (Cameron)	India	Butani (1972)	L	Sugarcane	
	Ichneumonidae	*Cremastus* sp.	India	Butani (1958)	L	Sugarcane	
				Butani (1972)		Sugarcane	
	Tachinidae	*Sturmiopsis inferens* Tns.	India	David *et al.* (1989)	L	Sugarcane	
	Trichogrammatidae	*Trichogramma chilonis* (Ishii)	India	Tuhan & Pawar (1983)	E	Sugarcane	Mass releases in the Punjab resulted in high rates of parasitism (>70%).
***Emmalocera depressella* Swinhoe**							
Parasitoids							
	Bethylidae	*Goniozus* sp.	India	Bhatt *et al.* (1996)	L	Sugarcane	
	Braconidae	*Ascogaster* sp.	India	Butani (1958)	L	Sugarcane	
				Butani (1972)		Sugarcane	
			Pakistan	Butani (1972)		Sugarcane	
	"	*Chelonus* sp.	India	Butani (1958)	L	Sugarcane	
	"	*Chelonus narayani* Subba Rao	India	Butani (1972)	?	Sugarcane	
		Phanerotoma hendecasiella Cam.	India	Box (1953)	?	Sugarcane	
	"	*Rhaconotus scirpophagae* Wilkinson	India	Box (1953)	L	Sugarcane	
	"	*Stenobracon deesae* Cameron	India	Box (1953)	L	Sugarcane	
	"	*Vipio* (*Stenobracon, Bracon, Glyptomorpha*)					

* New record.

		deesae (Cameron)	India	Butani (1972)	L	Sugarcane	
	Chalcididae	*Neohybothorax* sp.[#]	India	Sardana (1994)	?	Sugarcane	
	Trichogrammatidae	*Trichogramma australicum* Girault	India	Butani (1972)	E	Sugarcane	
	"	*Trichogramma chilonis* (Ishii)	Pakistan	Ashraf & Fatima (1996)	E	Sugarcane	
			India	Sardana (2000)		Sugarcane	
	"	*Trichogramma minutum* Riley	India	Box (1953)	E	Sugarcane	
Pathogens							
	Hypomycetes	*Beauveria bassiana* (ITCC No. 4512)	India	Sardana (1997b)	L	Sugarcane	
	"	*Metarhizium anisopliae* (ITCC No. 4514)	India	Sardana (1997b)	L	Sugarcane	
***Scirpophaga excerptalis* Walker**							
Parasitoids							
	Braconidae	*Apanteles* (*Cotesia*) *flavipes* Cam.	Philippines	Alba (1990)	L	Sugarcane	
			Thailand	Suasa-ard & Charernsom (1995)		Sugarcane	
	"	*Glyptomorpha* (=*Stenobracon*) *nicevillei* Bingham	India	Tanwar &Varma (1997)	L	Sugarcane	
	"	*Pseudoshirakia* sp.	India	Tanwar &Varma (1997)	L	Sugarcane	
				Dey (1998)		Sugarcane	
	"	*Rhaconotus* sp.	India	Pandey *et al.* (1997a)	L	Sugarcane	
	"	*Rhaconotus scirpophagae* Wlk.	India	Mukunthan (1989)	L	Sugarcane	
				Gupta *et al.* (1994)		Sugarcane	Parasitism levels of up to 33.42% were recorded in North Bihar, India.
				Tanwar &Varma (1997)		Sugarcane	
	"	*Stenobracon deesae* Cam.	India	Mukunthan (1989)	P(?)[*]	Sugarcane	
				Gupta *et al.* (1994)		Sugarcane	Up to 54.23% parasitism levels were recorded in North Bihar, India.
	"	*Spathius* sp.	India	Tanwar &Varma (1997)	L	Sugarcane	
	Eucoilidae	*Rhoptromeris* sp.	India	Pandey *et al.* (1997a)	L	Sugarcane	
	Elasmidae	*Elasmus zehntneri* Ferr.	India	Gupta *et al.* (1994)	L	Sugarcane	Low parasitism levels (<15%) were recorded in North Bihar, India.
				Tanwar (1990)		Sugarcane	
				Pandey *et al.* (1997a)		Sugarcane	
				Tanwar & Varma (1997)		Sugarcane	
	Ichneumonidae	*Isotima javensis* Rhower	India	Mukunthan (1989)	P	Sugarcane	
				Easwaramoorthy *et al.* (1992)		Sugarcane	
				Gupta *et al.* (1994)		Sugarcane	Parasitism

[#] New record.
[*] *Stenobracon deesae* Cam. is a larval parasitoid, this record could be a misidentification or possibly an error.

							levels of 6.67-15.28% were recorded in North Bihar, India.
				Pandey *et al.* (1997a)		Sugarcane	
				Tanwar & Varma (1997)		Sugarcane	
	"	*Temelucha* sp.	India	Pandey *et al.* (1997a)	L	Sugarcane	
				Tanwar & Varma (1997)		Sugarcane	
	"	*Temelucha philippinensis* (Ashmead)	Thailand	Suasa-ard & Charernsom (1995)	L	Sugarcane	
	"	*Xanthopipmla pedator* F.	India	Mukunthan (1989)	P	Sugarcane	
	Scelionidae	*Telenomus dignoides* Nixon	Philippines	Alba (1990)	E	Sugarcane	
		Telenomus dignus Gahan	India	Pandey *et al.* (1997a)	E	Sugarcane	
				Tanwar & Varma (1997)		Sugarcane	
			Philippines	Alba (1990)	E	Sugarcane	
		Telenomus rowani (Gahan)	Thailand	Suasa-ard & Charernsom (1995)	E	Sugarcane	
	Trichogrammatidae	*Trichogramma* sp.	Philippines	Alba (1991)		E	Sugarcane
	"	*Trichogramma chilonis* Ishii	India	Pandey *et al.* (1997a)	E	Sugarcane	Mass released.
				Tanwar &Varma (1997)		Sugarcane	
	"	*Trichogramma chilotraeae* Nagarja & Nagarkatti	Thailand	Suasa-ard & Charernsom (1995)	E	Sugarcane	
	"	*Trichogramma fasciatum* (Perkins)	India	Pandya (1997)	E	Sugarcane	Introduced from Barbados.
	"	*Trichogramma japonicum* Ashmead	India	Pandey *et al.* (1997a)	E	Sugarcane	Mass released.
Pathogens							
	Heterorhabditidae	*Heterorhabditis indicus* n. sp.	India	Poinar *et al.* (1992)	L	Sugarcane	
***Scirpophaga nivella* (Fabr.)**							
Parasitoids							
	Bethylidae	*Goniozus indicus* Ashmead (*cuttackensis* Lal)	India	Box (1953)	L	Sugarcane	
				Butani (1958)		Sugarcane	
				Butani (1972)		Sugarcane	
	"	*Goniozus* sp.	India	Butani (1958)	L	Sugarcane	
			India	Butani (1972)		Sugarcane	
	Braconidae	*Allorhogas pyralophagus* Marsh	Indonesia	Ubandi & Sunaryo (1986)	L	Sugarcane	Originally from Mexico. Introduced into Indonesia in 1982. Recovered from release sites. Impact on pest unclear.
	"	*Apanteles flavipes* Cameron (*nonagriae* Ol. & Vier)	India	Butani (1958)	L	Sugarcane	
		Apanteles (*Cotesia*) *flavipes* Cameron (*nonagriae* Olliff. nec Viereck, *Stenopleura simplicis* Viereck)	India	Butani (1972)	L	Sugarcane	
	"	*Apanteles scirpophagae* Ashmead	India	Box (1953)	L	Sugarcane	
				Butani (1972)		Sugarcane	
	"	*Apanteles* sp.	Indonesia	Samoedi & Wirioatmodjo (1986)	L	Sugarcane	
			Philippines	Box (1953)		Sugarcane	
	"	*Bracon* (*Amyosoma, Microbracon*) *chinensis*					

	(*albolineatus* Cameron, *chilonis* Viereck)	India	Butani (1972)	L	Sugarcane	
"	*Bracon famulus* Bingham	India	Butani (1972)	L	Sugarcane	
"	*Campyloneurus mutator* Fabricius	India	Butani (1972)	L	Sugarcane	
"	*Chilonis* sp.	India	Box (1953)	L	Sugarcane	
			Butani (1958)		Sugarcane	
			Butani (1972)		Sugarcane	
"	*Iphiaulax famulus* Bingham	India	Butani (1972)	L	Sugarcane	
"	*Iphiaulax sikkimenis* Cameron	India	Butani (1972)	L	Sugarcane	
"	*Iphiaulax* sp.	India	Butani (1972)	L	Sugarcane	
"	*Macrocentrus jacobsoni* Szépl.	Taiwan	Box (1953)	L	Sugarcane	
"	*Rhaconotus roslinesis* Lal	India	Butani (1958)	L	Sugarcane	
"	*Rhaconotus roslinensis* Lal (=*caulicola* Muesebeck)	India	Butani (1972)	L	Sugarcane	
"	*Rhaconotus schoenobii* Roh.	Philippines	Box (1953)	?	Sugarcane	
"	*Rhaconotus scirpophagae* Wilkinson	India	Box (1953)	L	Sugarcane	
			Butani (1958)		Sugarcane	
			Butani (1972)		Sugarcane	
			Goel *et al.* (1983)		Sugarcane	
		Pakistan	Carl (1962)		Sugarcane	The most common larval parasitoid on this host in Pakistan.
"	*Rhaconotus signipennis* Walker	India	Butani (1972)	L	Sugarcane	
"	*Shirakia yokohamensis* Cam.	Taiwan	Box (1953)	L	Sugarcane	
	Shirakia sp.	India	Butani (1958)	?	Sugarcane	
"	*Stenobracon* sp.	Indonesia	Tan & Koh (1980)	L	Sugarcane	
"	*Stenobracon deesae* Cameron	India	Box (1953)	L	Sugarcane	
			Butani (1958)		Sugarcane	
		Pakistan	Carl (1962)		Sugarcane	Low levels of Parasitism recorded (typically less than 3.1%).
"	*Stenobracon karnalensis* Lal	India	Butani (1972)	L	Sugarcane	
"	*Stenobracon* (*Bracon*, *Glyptomorpha*) *karnalensis* Lal	India	Butani (1958)	L	Sugarcane	
"	*Stenobracon nicevillei* Bingham	India	Butani (1958)	L	Sugarcane	
			Butani (1972)		Sugarcane	
		India	Goel *et al.* (1983)		Sugarcane	
"	*Stenobracon trifasciatus* Szépl.	Taiwan	Box (1953)	L	Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
			Kalshoven (1981)		Sugarcane	
			Samoedi & Wirioatmodjo (1986)		Sugarcan	
"	*Vipio* (*Stenobracon, Bracon, Glyptomorpha*) *deesae* (Cameron)	India	Butani (1972)	L	Sugarcane	
"	*Vipio* sp.	India	Butani (1972)	L	Sugarcane	
Chalcididae	*Bephratoides saccharicola* Mani	India	Butani (1958)	?	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Harmoniae* sp.	India	Butani (1958)	L	Sugarcane	
			Butani (1972)		Sugarcane	
		Pakistan	Butani (1972)		Sugarcane	

Elasmidae	*Elasmus* sp.	Taiwan	Box (1953)	?	Sugarcane	
		Indonesia	Tan & Koh (1980)	L	Sugarcane	
“	*Elasmus zehntneri* Ferriere	India	Butani (1958)	L	Sugarcane	
			Butani (1972)		Sugarcane	
		Indonesia	Box (1953)	L	Sugarcane	
			Kalshoven (1981)		Sugarcane	
			Ubandi *et al.* (1988)		Sugarcane	Mass released.
			Samoedi & Wirioatmodjo (1986)		Sugarcane	
		Pakistan	Carl (1962)		Sugarcane	Very low levels of parasitism recorded.
		Philippines	Box (1953)		Sugarcane	
Eulophidae	*Anostocetus* sp.	India	Butani (1958)	L	Sugarcane	
"	*Aprostocetus* sp.	India	Butani (1972)	P	Sugarcane	
"	*Tetrastichus ayyari* Rohwer	India	Butani (1972)	P	Sugarcane	
"	*Tetrastichus schoenobii* Ferriere	Indonesia	Mohyuddin (1986)	E	Sugarcane	
“	*Tetrastichus* sp.	India	Butani (1958)	?	Sugarcane	
		Indonesia	Tan & Koh (1980)	L	Sugarcane	
"	*Tetrastichus scirpophaga* Mani	India	Butani (1972)	E	Sugarcane	
"	*Tetrastichus* sp.	India	Butani (1972)	?	Sugarcane	
"	*Tetrastichus schoenobii* Ferr.	India	Butani (1972)	E	Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
Ichneumonidae	*Amauromorpha schoenobii* Vier.	Taiwan	Box (1953)	?	Sugarcane	
"	*Anomalon* sp.	India	Butani (1972)	L	Sugarcane	
"	*Centeterus alternecoloratus* Cushman	India	Butani (1972)	P	Sugarcane	
"	*Cremastus* sp.	India	Butani (1972)	L	Sugarcane	
"	*Exetastes longicornis* Ishida	Taiwan	Box (1953)	?	Sugarcane	
"	*Gambroides dammermani* Rohw.	Philippines	Box (1953)	?	Sugarcane	
"	*Gambroides javensis* Rohw.	Philippines	Box (1953)	?	Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
"	*Goryphus basilaris* Holmgren (*Exetastes*, *Mesosternus longicornis* Ishida)	India	Butani (1972)	?	Sugarcane	
"	*Goryphus* sp.	India	Butani (1958)	L?	Sugarcane	
			Butani (1972)	L?	Sugarcane	
"	*Ischnojoppa luteator* Fab.	India	Butani (1972)	P	Sugarcane	
"	*Isotima dammermani* Rohwer	India	Butani (1972)	P	Sugarcane	
"	*Isotima* sp. (a and b)	Pakistan	Carl (1962)	L	Sugarcane	Low parasitism levels recorded.
"	*Isotima javensis* Rohwer	India	Goel *et al.* (1983)	L	Sugarcane	
			Pawar (1987)	PP	Sugarcane	A key parasitoid of this pest in India.
		Indonesia	Kalshoven (1981)	P	Sugarcane	
			Samoedi & Wirioatmodjo (1986)		Sugarcane	
	Isotima (*Melcha*, *Gambroides*, *Eripernimorpha javensis* Rohwer	India	Butani (1972)	?	Sugarcane	
"	*Kriegeria heptazonata* Ashm.	Philippines	Box (1953)	?	Sugarcane	
"	*Kriegeria* sp.	India	Butani (1972)	?	Sugarcane	

"	*Listrognathus* (*Mesostenoideus*) *calvinervis* Cameron	India	Butani (1958)	L	Sugarcane	
"	*Melcha ornatipennis* Cameron	India	Box (1953)	?	Sugarcane	
			Butani (1958)	P	Sugarcane	
		Burma	Box (1953)		Sugarcane	
"	*Mesostenus longicornis* Ishida	India	Box (1953)	?	Sugarcane	
"	*Pimpla predator* Fabricius	India	Box (1953)	P	Sugarcane	
"	*Syzeuctus* sp.	India	Butani (1972)	L	Sugarcane	
"	*Temelucha* sp.	India	Butani (1972)	L	Sugarcane	
"	*Xanthopimpla stemmator* Thunberg	Taiwan	Takano (1934)	P	Sugarcane	
			Box (1953)		Sugarcane	
"	*Xanthopimpla (Ichneumon) stemmator* Thunberg (*thoracalis* Krieger, *bimaculata* Cameron, *maculifrons* Cameron, *nursei* Cameron, *fascialis* Szepligetti, *Habropimpla sesamiae* Rao)	India	Butani (1972)	P	Sugarcane	
Pteromalidae	*?Dinarmus* sp.	Indonesia	Kalshoven (1981)	L?	Sugarcane	
Scelionidae	*Telenomus* (*Ceraphron*, *Phanurus*, *Praphanurus*)					
"	*beneficiens* (Zehntner) Nixon	India	Butani (1958)	E	Sugarcane	
"	*Telenomus* (*Phanurus*, *Praphanurus*)					
	beneficiens (Zehntner) (Ceraphron)	India	Butani (1972)	E	Sugarcane	
"	*Telenomus beneficiens* (Zehntner)	India	Box (1953)	E	Sugarcane	
		Indonesia	Box (1953)		Sugarcane	
			Kalshoven (1981)	E	Sugarcane	
			Samoedi & Wirioatmodjo (1986)		Sugarcane	
		Philippines	Box (1953)		Sugarcane	
"	*Telenomus beneficiens* var. *elongatus* Ishida	Taiwan	Box (1953)	E	Sugarcane	
			Cheng *et al.* (1999c)		Sugarcane	The key egg parasitoid of this borer in cane fields of Taiwan.
"	*Telenomus dignus* Gahan	India	Butani (1958)	E	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Telenomus dignoides* Nixon	Indonesia	Mohyuddin (1986)	E	Sugarcane	
		Pakistan	Carl (1962)		Sugarcane	
		India	Butani (1958)		Sugarcane	
			Butani (1972)		Sugarcane	
"	*Telenomus rowani* Gahan	India	Butani (1958)	E	Sugarcane	
			Butani (1972)		Sugarcane	
"	*Telenomus saccharicola* Mani	India	Butani (1972)	E	Sugarcane	
"	*Telenomus* sp.	India	Butani (1972)	E	Sugarcane	
		India	Goel *et al.* (1983)		Sugarcane	
		Indonesia	Tan & Koh (1980)	E	Sugarcane	
Tachinidae	*Sturmiopsis inferens* Townsend	India	Butani (1972)	L	Sugarcane	
Trichogrammatidae	*Trichogramma* sp.	Indonesia	Samoedi & Wirioatmodjo (1986)	E	Sugarcane	
"	*Trichogramma chilonis* (Ishii)	China	Liu *et al.* (1996)	E	Sugarcane	
		Taiwan	Cheng *et al.* (1987b)		Sugarcane	
		Pakistan	Ashraf & Fatima (1996)		Sugarcane	Mass released.
"	*Trichogramma evanescens minutum* Riley	India	Butani (1958)	E	Sugarcane	

	“	*Trichogramma australicum* Girault	India	Butani (1972)	E	Sugarcane	
	"	*Trichogramma japonicum* Ashm.	Taiwan	Cheng & Chen (1991)	E	Sugarcane	
	“	*Trichogramma nanum* Zhnt.	Indonesia	Box (1953)	E	Sugarcane	
Predators							
	Coccinellidae	*Brumus suturalis* F.	India	Butani (1958)	E	Sugarcane	
	"	*Brumus* (*Coccinella*) *suturalis* Fabricius	India	Butani (1972)	E	Sugarcane	
	Formicidae	*Monomorium* sp.	India	Butani (1972)	L, P	Sugarcane	
<u>Family: Tortricidae</u>							
		Argyroploce (Tetramoera) schistaceana (Snellen)					
Parasitoids							
	Braconidae	*Cotesia flavipes*	Taiwan	Cheng *et al.* (1987a)	L	Sugarcane	
	Trichogrammatidae	*Trichogramma* sp.	Mauritius	Facknath (1989)	E	Sugarcane	
			Philippines	Alba (1991)	E	Sugarcane	
	"	*Trichogramma* sp. (?*australicum* Gir.)	Mauritius	Moutia & Courtois (1952)	E	Sugarcane	
				Williams (1978)		Sugarcane	
	"	*Trichogramma batra batra*	Philippines	Alba (1990)	E	Sugarcane	
	"	*Trichogramma chilonis*	Taiwan	Cheng *et al.* (1987b)	E	Sugarcane	
			Philippines	Alba (1990)	E	Sugarcane	
	"	*Trichogramma chilotraea*	Philippines	Alba (1990)	E	Sugarcane	
	"	*Trichogramma confusum* (*chilonis*)	China	Wang *et al.* (1985)	E	Sugarcane	
	"	*Trichogramma dendrolimi*	China	Wang *et al.* (1985)	E	Sugarcane	
	"	*Trichogramma* sp. nr. *nana* Zehnt.	Mauritius	Moutia & Courtois (1952)	E	Sugarcane	
				Williams (1978)	E	Sugarcane	
	"	*Trichogramma nubilali* Ertle & Davis	China	Liu *et al.* (1987)	E	Sugarcane	Introduced from USA in (1983).
	"	*Trichogramma ostriniae*	Taiwan	Cheng *et al.* (1995)	E	Sugarcane	
			China	Wang *et al.* (1985)		Sugarcane	
	"	*Trichogramma japonicum*	China	Wang *et al.* (1985)	E	Sugarcane	
	"	*Trichogrammatoidea nana* Zehnt.	Indonesia	Pan & Lim (1979)	E	Sugarcane	Mass released
			Philippines	Alba (1990)	E	Sugarcane	The main egg parasitoid, 91% parasitism rates recorded.
Predators							
	Formicidae	*Pheidole megacephala* Fab.	Mauritius	Williams (1978)	?	Sugarcane	

Symbols used in the table: E = egg, L = larva, PP = pre pupa, and P = pupa. A question mark indicates an unknown or a doubtful status of record.

Classical biological control of introduced pests offers an ecologically soft and acceptable approach in pest management. The previous table lists 794 records of natural enemies of 18 key pests of gramineous plants. Based on this list and other previous studies, *Cotesia flavipes* stands out as an efficient natural enemy of most of the key stem boring pests in the neighbouring countries. According to the previous table, *Cotesia flavipes* is capable of parasaitizing 15 out of 18 stemborer pest species distributed in Asia and Indian Ocean islands. Though there are no records of *C. flavipes* attacking *Sesamia calamistis* in Mauritius, the parasitoid is frequently recorded to attack that host in mainland Africa (see Ngi-Song et al 1995; Polaszek 1998; Sallam *et al.* 1999; Sallam *et al*. 2001). Other *Chilo* species, such as *C. orichalcociliellus* for example, is also attacked by *C. flavipes* in corn in main land Africa (see Ngi-Song *et al.* 1995; Potting 1996). *C. flavipes* is also recorded to parasitize a fairly wide range of stemborer species of the new world genus *Diatraea*, as well as the Mexican rice borer, *Eoreuma loftini* Dyar (Lepidoptera: Pyralidae) in corn in South America and southern USA (Rodriguez-del-Bosque *et al.* 1990; see also Potting 1996; Overholt *et al.* 1997). However, the record of *Apanteles* (*Cotesia*) *flavipes* on *Scirpophaga excerptalis* is doubtful (see table), since female parasitoids are incapable of reaching host larvae inside the growing point, though may accept stinging the host under laboratory conditions (Sallam, personal observation). On the other hand, *C. flavipes* is recorded on other *Scirpophaga* species in Asia, such as *S. innotata* and *S. incertulas* in rice fields (Nath & Hikim 1978; Reissing *et al.* 1986).

C. flavipes is a species originally native to the Indo Australian region, and it has been introduced into a number of countries for the control of different pyralid and noctuid stemborer pests. Some remarkable successes of the establishment of this species are reported, for example, Appert *et al.* (1969) report a 2000 tons reduction in sugar losses in one state of Madagascar due to the control of *C. sacchariphagus* following the introduction of *C. flavipes* in the late fifties. In Barbados, *C. flavipes* was introduced from India in 1966 and recorded to have achieved parasitism levels of up to 80% against *Diatraea saccharalis* (Simmonds 1969). The same parasitoid was also introduced into Brazil, where it is continuously mass released for the control of *Diatraea saccharalis* in cane. Though the Brazilian approach does not strictly fit the definition of classical biological control given that the parasitoid is extensively used in augumentative releases, *C. flavipes* resulted in a reduction in infestation levels by about 50% (Macedo *et al.* 1993). However, a successful classical biological control program should incorporate a range of natural enemies attacking different host stages and with a variety of attack methods to have maximum impact on the pest population. Stemborer parasitoids can be classified according to the host stage they attack into: egg parasitoids, egg-larval parasitoids, early-larval endoparasitoids, late-larval endoparasitoids, larval ectoparasitoids, prepupal ectoparasitoids, larval-pupal endo parasitoids and pupal endoparasitoids (Smith *et al.* 1993). Another approach of classifying stemborer parasitoids based on their foraging strategy is presented by Smith & Wiednenmann (1997). According to that approach, parasitoid attack methods are classified into: direct attack, drill and sting, probe and sting, wait and sting, ingress and sting, planidial ingress and bait and wait (see Smith & Wiednenmann (1997) for more details). A knowledge of host stage attacked and parasitoid foraging behaviour is essential before deciding on the introduction of a natural enemy into a new country. Primarily, a knowledge of the endemic natural enemy complex attacking an introduced pest in the country it invaded is required. This information is needed to identify which host stage is to be targetted. For example, in South Africa, where a classical biological control program has been tried against *Eldana saccharina*, it was realized that the introduction of egg parasitoids had no impact on the host (Conlong 1997). This was attributed to the fact that a large proportion of eggs and neonate larvae are already eaten by predators. This agrees with Hamburg & Hassell (1984), who showed that the impact of an additional mortality factor that targets a stage with already high natural mortality is negligible. Alternatively, in Mozambique, where *Chilo sacchariphagus* was confirmed to be attacking sugarcane for the first time in 1999 (Way & Turner 1999), it was decided to introduce the pupal parasitoid, *Xanthopimpla stemmator* Thunberg (Hymenoptera: Ichneumonidae). This decision was based on the fact that no indigenous pupal parasitoids were recorded in Mozambique to attack the introduced pest. Post release surveys in Mozambique showed a sharp reduction of *C. sacchariphagus* population in all release fields, with good potential for *X. stemmator* to colonize the new environment (Conlong & Goebel 2002). Based on the list presented in this study, *X. stemmator* is recorded on 8 key stemborers in a number of Asian countries, therefore may act as an important candidate for introduction to Australia in case of incursion by any of its stemborer hosts. No direct competition between *C. flavipes* and *X. stemmator* is expected as they attack different host stages and use different attack strategies. *C. flavipes* uses an "ingress & sting" strategy, whereby female parasitoids gain ingress through the host tunnel and sting the larva inside. On the other hand, *X. stemmator* uses a "drill and sting" strategy, whereby a femal parasitoid pierces the plant stem directly with the ovipositor and reach the pupa inside the chamber (Smith *et al.* 1993). Both parasitoid species were introduced into the Indian Ocean island of Mauritius, where they contribute to the natural mortality of the spotted stemborer *Chilo sacchariphagus* in sugarcane (Ganeshan 2000).

Status of *Cotesia flavipes* in Australia

In Australia, the name *Apanteles nonagriae* is cited as a synonym of *Apantelis* (*Cotesia*) *flavipes* (Austin & Dangerfield 1992), however the two could be sibling species. Records of *A. nonagriae* in Australia go back as far as 1920 when Jarvis (1927) recorded it parasitising *Phragmatiphila truncata* Walker (*Bathytrica truncata*). The author refers to *P. truncata* larvae collected at Pyramid (South Mulgrave) in 1921 that yielded the parasitoid. He also mentioned that both *A. nonagriae* has been previously recorded on *P. truncata* in New South Wales where it was responsible for 50% parasitism. In 1934, as mentioned before, Bell recorded *Apanteles flavipes* (*nonagriae*) on *B. truncata* larvae in Mackay, Central Queensland. Later in 1970, Li recorded *Apanteles flavipes* (*A. nonagriae*) from *Chilo suppressalis* and *Chilo polychrysa* in rice fields in the Northern Territory. The occurrence of *Cotesia flavipes* in Australia is therefore an area that requires more studies, especially when it is recorded to exploit most of the lepidopterous stemborers mentioned in this review. The fairly wide host range of *C. flavipes* qualifies it to be a strong candidate in case of incursion of some of the most important borer species into Australia. Weather the Australian population is capable of exploiting the exotic stemborers or there is need to introduce another population is an interesting point to investigate. It will also be useful if different populations of *C. flavipes* are tested on some of the key borer species in the neighbouring countries; this information will help determine the most suitable population to be considered for introduction and if there is actually a need for parasitoid introduction into Australia in case of a pest incursion.

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References

Abdul Mannan M & Iwahashi O. 1999. Seasonal changes in infestation level of sugarcane by the pink borer, *Sesamia inferens* (Lepidoptera: Noctuidae), in relation to a parasitoid, *Cotesia flavipes* (Hymenoptera: Braconidae), on Okinawa Island. *Applied Entomology and Zoology* **34(4),** 429-434.

Agrawal RA. 1964. Biology of sugarcane internode borer (*Proceras indicus* K.). *Indian Sugar* **14,** 145-150, 156.

Alagesan K, Mahendran VP & Pandian KRG. 1991. A new pest of Tamil Nadu recorded in the Vellore Co-op. Sugar Mills area. *SISSTA Sugar Journal* **16(2),** 13-15.

Alam MM, Beg MN & Ghani MA. 1972. Introducton of *Apanteles* spp. against graminaceous borers into Pakistan. *Technical Bulletin, Commonwealth Institiute of Biological Control* **15,** 1-10.

Alam N, Ramashrit S & Mishra SB. 1993. Impact of weeds and methods of weed control on the incidence of stemborers (*Scirpophaga incertulas* Wlk., *Chilo suppressalis* Wlk. and *Sesamia inferens* Wlk.) in deep water rice. *Journal of Entomological Research* **17(2),** 125-128.

Alba MC. 1989. Prospects and problems of biological control in sugarcane. *PHILSUTECH Proceedings* **36,** 144-153.

Alba MC. 1990. Use of natural enemies for controlling sugarcane pests in the Philippines. FFTC-NARC International Seminar on 'The use of parasitoids and predators to control agricultural pests', Tukuba Science City, Japan, October 2-7, 1989. National Agricultural Research Centre (NARC).

Alba MC. 1991. Utilization of *Trichogramma* for biological control of sugarcane borers in the Philippines. *Colloques de l'INRA* **56,**161-163.

Allsopp PG & Sallam MN. 2001. *Sesamia* incursion management plan - Version 1. *BSES Internal Report* PR01002.

Allsopp PG, Samson P & Chandler K. 2000. Pest management. In *Manual of canegrowing*, Brisbane, Hogarth DM & Allsopp PG (eds). 436pp.

Anonymous. 1954. Review of agricultural entomology during the period 1948-1954. *Report of the VIth commonwealth entomological conference* 281-284.

Anonymous. 1996. NAQS detects pests on Torres Strait Island. *AQIS Bulletin* **9(14),** 8-9.

Appert J 1973. Entomofaune parasitaire des foreurs des gramines a Madagascar. *Entomophaga* **18 (1),** 77-94.

Appert J. 1975. Examples des méthodes d'élévage et de dissémination des parasites et prédateurs d'intérêt économique à Madagascar. In: *Rapport du premier en formation à la lutte contre les enemies des cultures et plus spécialement al lutte contre le criquet pélérin at aux recherches sur cet acridien, 17 fev. 1976*. FAO Rome, pp. 239-242.

Appert J, Betbeder-Matibet M & Ranaivosoa H. 1969. Vingt années de lutte biologique à Madagascar. *Agronomie Tropicale* **26,** 555-572.

Arakaki N & Ganaha Y. 1986. Emergence pattern and mating behavior of *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae). *Applied Entomology and Zoology* **21 (3),** 382-388.

Arora, G S. 2000. Studies on some Indian Pyralid species. *Records of the Zoological Survey of India* **181,** i-vii, 169 pp. (ed.) ZSI, Calcutta.

Ashraf M & Fatima B. 1996. Success of *Trichogramma chilonis* (Ishii) for area-wide control of sugarcane borers in Pakistan. Brighton Crop Protection Conference: Pests & Diseases Vol. (1) *Proceedings of an International Conference, Brighton, UK*, 18-21 November 1996. 385-388.

Atwal AS. 1962. Appearance of stalk borer, *Chilo auricilius* Dudg. (Crambidae: Lep.) in Punjab. *Indian Journal of Sugarcane Research and development* **7,** 57.

Austin AD & Dangerfield PC. 1992. Synopsis of Australian microgastrinae (Hymenoptera: Braconidae), with a key to genera and description of new taxa. *Invertebrate Taxonomy* **6,** 1-76.

Barrion AT, Catindig JLA, Litsinger JA. 1990. *Chilo auricilius* Dudgeon (Lepidoptera: Pyralidae), the correct name for the dark-headed stem borer (SB) found in the Philippines. *International Rice Research Newsletter* **15(4),** 29.

Barrion AT, Libetario EM, Litsinger JA. 1987. An earwig predator of Asian pink stem borer (PSB) on upland rice. *International Rice Research Newsletter* **12(1),** 21.

Bell, AF. 1934. Annual Report. Bureau of Sugarcane Experiment Stations, Qld. **34:** 71.

Betbeder-Matibet M. 1989. Biological control of sorghum stem borers. International Workshop on Sorghum Stem Borers, 17-20 Nov 1987. ICRISAT. Patancheru. India. 89-93.

Betbeder-Matibet M & Malinge P. 1968. Un succès de la lutte biologique: contrôl de *Proceras sacchariphagus* Boj. (Borer ponctue) de la canne à sucre à madagascar par un parasite introduït: *Apanteles flavipes* Cam. *Agronomie Tropicale* **22,** 1196-1220.

Bhatt TA, Vyas ST, Mehta VR, Patel KK, Patel JM. 1996. Natural parasitism in sugarcane root borer. *Bharatiya Sugar* **22(3),** 37-39.

Bin F & Johnson NF. 1982. Some new species of *Telenomus* (Hym., Scelionidae) egg-parasitoids of tropical pyralid pests (Lep., Pyralidae). *Redia* **65,** 229-252.

Bleszynski S.(1970. A revision of the world species of *Chilo* Zincken (Lepidoptera, Pyralidae). *Bulletin of the British Museum* (Natural History) (Entomology) **25,** 101-195.

Borah BK & Arya MPS. 1995. Natural parasitization of sugarcane plassey borer (*Chilo tumidicostalis* HMPSN.) by braconid larval parasitoid in Assam. *Annals of Agricultural Research* **16(3),** 362-363.

Borah BK & Sarma KK. 1995. Seasonal incidence of plassey borer, *Chilo tumidicostalis* Hmpsn. in ratoon sugarcane. *Plant Health* **1,** 29-33.

Box HE. 1953. List of sugar-cane insects. Commonwealth Institute of Entomology, London. 103 pp.

Brenière J, Bordat D, Vercambre B, Hamza H & Renand M. 1985. Les operations de lutte biologique contre le foreur du mais *Chilo partellus* (Swinhoe) Lepidoptera, dans l'ile de Ngazidja. *Agronomie Tropicale* **40,** 157-166.

Brenière J, Pfeffer P, Betbeder-Matibet, M & Etienne J. 1966. Tentative d'introduction à Madagascar et a la Rèunion de *Diatraeophaga striatalis* parasite de *Proceras sacchariphagus*-boreur ponctué de la canne à sucre. *Entomophaga* **11,** 231-238.

Butani DK. 1957. A tachinid fly parasite of *Chilo zonellus* Swin. *Indian Journal of Entomology* 19**,** 62-63.

Butani DK. 1958. Parasites and predators recorded on sugarcane pests in India. *Indian Journal of Entomology* **20,** 270-282.

Butani DK. 1972. Parasites and predators recorded on insect pests of sugarcane in India. *Indian Sugar* **22,** 17-32.

CAB. 1972. *Chilo infuscatellus* Sn. Distribution maps of pests No. 301. Commonwealth Agricultural Bureaux, Commonwealth Institute of Entomology, London.

CAB. 1977. *Chilo suppressalis* (Wlk.) Distribution Maps of Pests Seris A, Map no. 184. International Institute of Entomology, London.

CAB. 1989. Distribution Maps of Pests No. 254 (revised). Commonwealth Agricultural Bureaux, Commonwealth Institute of Entomology, London.

Caresche L. 1962. Les insectes nuisibles a la canne a sucre dans l'Ile de la Reunion. *Agronomie Tropicale* **17,** 632-646.

Carl KP. 1962. Gramineous moth borers in West Pakistan. *Technical Bulletin* CIBC **2,** 29-76 (RAE 51: p.277).

Carnegie AJM, Conlong DE & Graham DY. 1985. Recent introductions of parasitoids against *Eldana saccharina* Walker (Lepidoptera: Pyralidae). *Proceedings of the South African Sugar Technologists Association* **59,** 160-163.

Carnegie AJM & Leslie GW. 1991. Trends shown by light trap catches of some sugarcane pests. *Proceedings of the South African Sugar Technologists Association* 65**,** 87-91.

Chacko MJ & Rao VP. 1966. *Centeterus alternecoloratus* Cushman? var., a pupal parasite of the graminaceous borer *Chilo partellus* (Swinhoe) and *Chilotraea auricilia* (Dudgeon). *Entomphaga* **11,** 297-303.

Chandler KJ & Croft BJ. 1986. Quarantine significance of pests and diseases of sugarcane on the Torres Strait Islands. *Proceedings of Australian Society of Sugarcane Technologists* (28^{th} April - 1^{st} May) 129 - 133.

Chandra J & Avasthy PN. 1988. Effect of temperature variations on survival and development of Sturmiopsis inferens Tns. during winter months. *Indian Journal of Agricultural Research* **22(3),** 159-163.

Chaudhary JP & Chand N. 1972. First record of *Ceraphron fijiensis* Ferriere (Ceraphronidae: Hymenoptera): a hyperparasite of *Apanteles flavipes* Cameron (Braconidae: Hymenoptera) from India. *Indian Journal of Entomology* **34,** 179-180.

Cheng WY. 1986. Research on *Trichogramma chilonis* Ishii and its utilization for the control of sugarcane borers in Taiwan. *Plant Protection Bulletin, Taiwan* **28(1),** 41-58.

Cheng WY. 1994. Sugarcane stem borers of Taiwan. In: *Biology, Pest status and Control Measure Relationships of Sugarcane Insect Pests* (eds AJM Carnegie & Conlong) pp. 97-106. South African Sugar Association Experiment Station, Mt Edgecombe.

Cheng WY. 1999. Borer infestation of millable cane. *Report of the Taiwan Sugar Research Institute* No. 165, 1-14.

Cheng WY, Chang CH, Wang ZT. 1987a. Occurrence of *Cotesia flavipes* Cameron (Hym: Braconidae) in autumn sugarcane fields. *Report of the Taiwan Sugar Research Institute* **117,** 31-41.

Cheng WY & Chen SM. 1991. Occurrence of *Telenomus beneficiens* Var. e*longatus*, an egg parasitoid of the sugarcane top borer in spring cane. *Proceedings of the 23^{rd} ISSCT* **23(2),** 553-558.

Cheng WY, Chen SM & Wang ZT. 1995. Differences in occurrence of *Trichogramma chilonis* and *T. ostriniae* between spring cane and sweet corn fields. *Report of the Taiwan Sugar Research Institute* No. 150, 23-41.

Cheng WY, Chen SM & Wang ZT. 1999a. Occurrence of *Meloboris sinicus* (Holmgren) in spring cane. *Report of the Taiwan Sugar Research Institute* **No. 165,** 15-28.

Cheng WY, Chen SM, Wang ZT. 1999b. Survey of larval and pupal parasitoids of cane borers in spring cane. *Report of the Taiwan Sugar Research Institute* **No. 164**, 1-14.

Cheng WY, Chen SM, Singh V & Kumar V. 1999. Occurrence of *Telenomus beneficiens* var. *elongatus*, an egg parasitoid of the sugarcane top borer in spring cane. *Proceedings of the XXIII ISSCT Congress, India* **2,** 553-558.

Cheng WY, Hung TH, Hung JK & Wang ZT. 1987b. The occurrence of eggs of some sugarcane insect pests and egg parasitism by *Trichogramma chilonis* in the autumn-planted cane fields. *Report of the Taiwan Sugar Research Institute* **117,** 13-30.

Cheng WY, Wang ZT & Hung TH. 1997. Seasonal occurrence of the eggs of borers and other *Trichogramma* hosts in the spring-planted cane fields. *Report of the Taiwan Sugar Research Institute* **156,** 15-36.

Chundurwar RD. 1989. Sorghum stem borers in India and Southeast Asia. *International Workshop on Sorghum Stemborers, ICRISAT, India* 19-25.

CIBC. 1966. Final report on Investiations on the natural enemies of corn borer. Pakistan Station Commonwealth Institute of Biological Control.

CIE. 1967. Distribution maps of pests. *Sesamia inferens* (Wlk.). Map no. 237. Commonwealth Institute of Entomology, London.

Common IFB. 1960. A revision of the Australian stem borers hitherto referred to *Schoenobius* and *Scirpophaga* (Lepidoptera: Pyralidae, Schoenobiinae). *Australian Journal of Zoology* **8,** 307-347.

Conlong DE. 1997. Biological control of *Eldana saccharina* Walker in South African sugarcane: Constraints identified from 15 years of research. *Insect Science and its Application* **17(1),** 69-78.

Conlong DE. & Goebel R. 2002. Biological control of *Chilo sacchariphagus* (Lepidoptera: Crambidae) in Mozambique: The first steps. *Proceedings of the South African Sugarcane Technologists Conference* **76,** 310 - 320.
Cook M. 1997. Revision of the genus *Maliarpha* (Lepidoptera: Pyralidae), based on adult morphology with description of three new species. *Bulletin of Entomological Research* **87(1),** 25-36.
Cuong NL & Cohen MB. 2002. Field survey and greenhouse evaluation of non-rice host plants of the striped stemborer, *Chilo suppressalis* (Lepidoptera: Pyralidae), as refuges for resistance management of rice transformed with *Bacillus thuringiensis* toxin genes. *Bulletin of Entomological Research* **92,** 265-268.
Dai KJ, Zhang LW, Ma ZJ, Zhong LS, Zhang QX, Cao AH, Xu KJ, Li Q & Gao YG. 1988. Research and utilization of artificial host egg for propagation of parasitoid *Trichogramma*. Colloques de l'INRA. 43, 311-318; In *Trichogramma* and other egg parasites.
David H. 1986. The internode borer, *Chilo sacchariphagus indicus* (Kapur). In *Sugarcane Entomology in India* (Ed. David H, Easwaramoorthy S. & Jayanthi R. Sugarcane breeding institute, Coimbatore, India) pp. 121-134.
David H & Easwaramoorthy S. 1990. Biological control of *Chilo* spp. in sugar-cane. *Insect Science and its Application* **11(4/5),** 733-748.
David H, Easwaramoorthy S & Jayanthi R. 1991. Integrated pest management in sugarcane with special emphasis on biological control. Sugarcane Breeding Institute, Coimatore, India.
David H, Easwaramoorthy S, Kurup NK, Shanmugasundaram M & Santhalakshmi G. 1989. A simplified mass culturing technique for *Sturmiopsis inferens* Tns. *Journal of Biological Control* **3(1),** 1-3.
Dey D. 1998. New records of four braconid (Hymenoptera: Braconidae) genera from India. *Shashpa* **5(1),** 103-104.
Devi N & Raj D. 1996. Extent of parasitization of *Chilo partellus* (Swinhoe) on maize by *Apanteles* sp. in mid hill zone of Himachal Pradesh (India). *Journal of Entomological Research* **20(2),** 171-172.
Drinkwater TW. 1986. Ephysteris promptella (Staudinger) (Lepidoptera: Gelechiidae), a new pest of maize and grain sorghum in South Africa. *Phytophylactica* **18(4),** 221.
Eastwood D, Malein PJ & Young GR. 1998. Changes in sugarcane quality and yield through damage by *Sesamia grisescens*. *Sugarcane* No 1. 3-7.
Easwaramoorthy S, David H & Shanmugasundaram M. 1991. Laboratory technique for mass multiplication of pink borer, *Sesamia inferens* Walker (Noctuidae: Lepidoptera). *Entomon* **16(3),** 223-227.
Easwaramoorthy S, David H, Shanmugasundaram M, Santhalakshmi G & Kumar R. 1992. Laboratory and field evaluation of *Allorhogas pyralophagus* for the control of lepidopterous borers infesting sugarcane in tropical India. *Entomophaga* **37 (4),** 613-619.
Easwaramoorthy S & Jayaraj S. 1987. Cross infectivity of granulosis viruses infecting *Chilo infuscatellus* Snell and *C. sacchariphagus indicus* (Kapur). *Journal of Entomological Research* **11(2),** 170-174.
Easwaramoorthy S, Kurup NK & Santhalakshmi G. 1999. Record of *Bacillus cereus* infection on *Sturmiopsis inferens* Tns. puparia. *Insect Environment* **5(2),** 71-72.
Easwaramoorthy S & Nandagopal V. 1986. Life tables of internode borer, *Chilo sacchariphagus indicus* (K.), on resistant and susceptible varieties of sugarcane. *Tropical Pest Management*. **32(3)** 221-228, 257, 259.
Easwaramoorthy S, Nandagopal V, David H & Goel SC. 1983. Seasonal importance of parasites and predators on sugarcane internode borer, *Chilo sacchariphagus* indicus (K.). *Insect ecology and resource management* [edited by Goel, S.C.] 55-61.
Easwaramoorthy S, Santhalakshmi G, Shanmugasundaram M & David H. 1989. A cytoplasmic polyhedrosis virus of pink borer *Sesamia inferens* Wlk. (Noctuidae: Lepidoptera). *Entomon* **14(12),** 165-168.
Easwaramoorthy S, Srikanth J & Santhalakshmi G. 1996a. Seasonal occurrence of the fungus *Hirsutella nodulosa* Petch and granulosis virus of sugarcane internode borer *Chilo sacchariphagus indicus* (Kapur). *Entomon* **21(3-4),** 205-209.
Easwaramoorthy S, Srikanth J, Santhalakshmi G & Kurup NK. 1996b. Life history and prey acceptance of commonly occurring spiders in sugarcane ecosystem. *Journal of Biological Control* **10 (1-2)**, 39-47.
Easwaramoorthy S, Strongman DB & Santhalakshmi G. 1998. Record of *Hirsutella nodulosa* Petch from *Chilo sacchariphagus* indicus (Kapur), sugarcane internode borer in India. *Journal of Biological Control* **11(1-2),** 79-80.
El-Amin EM. 1984. Relative susceptibility of seven sugarcane varieties to the stem borer, *Sesamia cretica* Led., under conditions of natural infestation at Sennar, Sudan. *Beitrage zur tropischen Landwirtschaft und Veterinarmedizin* **22(1),** 73-77.
Facknath S. 1989. Biological control of sugar-cane pests in Mauritius: A case study. *Insect Science and its Application* **10(6),** 809-813.
FitzGibbon F, Allsopp PG & De Barro PJ. 1998. Sugarcane Exotic Pests – Pest Risk Analysis Database. CD98001. Bureau of Sugar Experiment Stations, Brisbane.
Ganeshan S. 2000. Biological control of sugarcane pests in Mauritius: current status and future prospects. *Proceedings of the IV Sugarcane Entomology Workshop, ISSCT, Thailand* 3-9.
Ganeshan S & Rajabalee A. 1997. Parasitoids of the sugarcane spotted borer, *Chilo sacchariphagus* (Lepidoptera: Pyralidae), in Mauritius. *Proceedings of the Annual Congress South African Sugar Technologists Association* **71,** 87-90.
Garg DK. 1988. Host range and overwintering of rice pink stem borer (PSB) in a hilly region of India. *International Rice Research Newsletter* **13(2),** 23-24.
Godse DB & Nayak P. 1983. Nuclear polyhedrosis of *Sesamia inferens* (Noctuidae: Lepidoptera) the pink stemborer of rice. *Current Science* **52(14),** 682-683.
Goebel R, Fernandez E, Beugue JM, Tibere R & Alauzet C. 2000. Predation and varietal resistance as important components of integrated protection of the sugarcane stemborer *Chilo sacchariphagus* (Bojer) (Lepidoptera: Pyralidae) in Reunion. *Proccedings of the IV Sugarcane Entomology Workshop, ISSCT, Thailand* 51- 56.
Goel SC, Roy TCD & Bains SS. 1983. Key mortality factors in the population dynamics of sugarcane top borer, *Tryporyza nivella* (Fabr) in the Punjab. *Insect ecology and resource management* Goel SC (ed.) 270-283.
Gough N & Peterson R. 1984. Cane stem borer on Torres Strait Islands. *BSES Bulletin* **8,** 20 –21.
Greathead DJ. 1971. A review of biological control in the Ethiopean region. Commonwealth Institute of Biological Control. *Technical Communication* No. 5.
Guo MF. 1988. New method of *Trichogramma* utilization. In *Trichogramma* and other egg parasites. *Colloques de l'INRA* **43,** 469-476.
Guo LZ, Feng RY, Liang EY, Wei DT & Kang FG. 2000. Infestation by *Tetramoera schistaceana* Snellen, *Chilo infuscatellus* Snellen and *C. sacchariphagus* of sugarcane plants and their control by chemicals. *Plant Protection* **26(1),** 23-25.
Gupta SC, Yazdani SS, Hameed SF & Agarwal ML. 1994. Seasonal prevalence of larval parasitoids of sugarcane top borer, *Scirpophaga excerptalis* in North Bihar (India). *Journal of Entomological Research* **18(1),** 83-87.
Haile A & Hofsvang T. 2001. Survey of lepidopterous stem borer pests of sorghum, maize and pearl millet in Eritrea. *Crop Protection* **20(2),** 151-157.
Halimie MA, Ahmad CS, Mehdi SA & Abrar H. 1989. Effect of shoot cutting frequency on reducing Gurdaspur borer infestation. *Journal of Agricultural Research Lahore* **27(2),** 139-142.

Halimie MA, Ahmad MR, Ahmad T & Ibrar H. 1994. Development of pest control technology for sugarcane crop. *Pakistan Sugar Journal* **8(1),** 13-14.

Harris KM. 1962. Lepidopterous stem borers of cereals in Nigeria. *Bulletin of Entomological Research* **53,** 139-171.

Harris KM. 1990. Biology of *Chilo* species. *Insect Science and its Application* **11,** 4/5, 467-477.

Hasmi AA & Rahim A. 1985. Pest management model for sugar-cane borers in Sind, Pakistan. *International Pest Control* **27,** 88-91.

Hattori I & Siwi SS. 1986. Rice stemborers in Indonesia. *JARQ* **20(1),** 25-30.

Hilal A. 1984. Study of the development and mortality of *Sesamia nonagrioides* (LEF.) (Lep.; Noctuidae) on different food plants and on an artificial medium. *Actes de l'Institut Agronomique et Veterinaire Hassan* II **4(1),** 5- 9.

Hilal A. 1985. Study of the technological alterations of sugarcane due to the attacks of *Sesamia nonagrioides* (LEF.) (Lep.; Noctuidae). *Actes de l'Institut Agronomique et Veterinaire Hassan* II **5(1-2),** 37-42.

Hill DS. 1983. Agricultural Insect Pests of the Tropics and Their Control. Cambridge University Press, London (ed.).

Heinrichs EA. 1998. Rice: West Africa. In: African Cereal Stem Borers. Economic Importance, Taxonomy, Natural Enemies and Control (ed. A Polaszek) pp. 49-57. CAB International, Wallingford.

Hirai Y. 1991. Major pests of maize and control measures in Japan. *Japan Agricultural Research Quarterly* **25(1),** 12-16.

Holloway JD. 1998. Noctuidae. pp 79-86. In A. Polaszek (ed.) African cereal stem borers: economic importance, taxonomy, natural enemies and control. CAB International, Wallingford, UK. 530 pp.

Hopper KR & Roush RT. 1993. Mate finding, dispersal, number released, and the success of biological control introductions. *Ecological Entomology* **18,** 321-331.

Huang RH, Huang PQ & Xiong CJ. 1985. Studies on the occurrence of *Chilo auricilius* Dudgeon in Yibing Prefecture, Shichuan. *Insect Knowledge* (*Kunchong Zhishi*) **22**, 104-106.

Husain M & Begum N. 1985. Seasonal stem borer (SB) population fluctuations in Mymensingh, Bangladesh. *International Rice Research Newsletter* **10(5),** 22.

Imamura, K & Machimura, N. 1976. Studies on the parasite, *Apanteles chilonis* Munakata, on the rice stem borer, *Chilo suppressalis* Walker, 4: Significance of overwintering larvae of rice stem borer, *Chilo suppressalis* Walker, in the stubbles of rice plant as initial source of the parasite. *Proceedings of the Association for Plant Protection of Hokuriku* (Japan) **24,** 45-50.

Imamura K & Yamazaki S. 1975. Studies on the parasite, *Apanteles chilonis* Munakata, on rice stemborer, *Chilo suppressalis* Wlker: Emerging habits. *Proceedings of the Association of Plant Protection. Hokuriku* **23,** 68-72.

Inayatullah C. 1983. Host selection by *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae): Influence of Host and Host Plant. *Journal of Economic Entomology* **76,** 1086-1087.

Ingram JW. 1948. The Lepidopterous stalk borers associated with Gramineae in Uganda. *Bulletin of Entomological Research* **49,** 367-383.

Ishida S, Kikui H & Tsuchida K. 2000. Seasonal prevalence of the rice stem borer moth, *Chilo suppressalis* (Lepidoptera: Pyralidae) feeding on water oats (*Zizania latifolia*) and the influence of its two egg parasites. *Research Bulletin of the Faculty of Agriculture, Gifu University* **65,** 21-27.

Jacob SA & Kochu BM. 1995. *Sesamia inferens* Walker - a new pest of oil palm seedlings in India. *Planter* **71(831),** 265-266.

Jacquemard P, Croizier G, Amargier A, Veyrunes JC, Croizier L, Bordat D & Vercambre B. 1985. Presence of three viruses in *Sesamia calamistis* Hampson (Lepidoptera: Agrotidae) on the island of Reunion. *Agronomie Tropicale* **40(1),** 66-71.

Jaipal S & Chaudhary JP. 1994. Laboratory studies on temperature tolerance in *Sturmiopsis inferens* Tns. (Tachinidae: Diptera). *Journal of Insect Science* **7(1),** 93-94.

Javier PA & Gonzalez P. 2000. Sugarcane borers. *Philsurin update* **IV(2),** 3 pp.

Jarvis D. 1927.Notes on insects damaging sugarcane in Queensland. *BESE Bulletin* 3, 94pp.

Jolly SC & Singh RP. 1990. Mechanical control of Gurdaspur borer (*Acigona steniella* (Hmpsn.)) in Yamunanagar (Haryana). *Proceedings of the 52nd Annual Convention of the Sugar Technologists' Association of India* 1989 Ag. 157-162.

Jones EL. 1966. Rice stem borer *Bathytrica truncata*. N.S.W. Department of Agriculture, Entomology branch. *Annual Report* 1965/66: 14-15.

Jotwani MG. 1982. Factors reducing sorghum yields: Insect pests. In *Sorghum in the eighties: proceedings of the International Symposium on Sorghum*, ICRISAT, India. Vol. 1.

Jotwani MG & Verma KK. 1969. *Menochilus sexmaculata* (Fabricius) as a predator of sorghum stemborer, *Chilo zonellus* (Swinh.). *Indian Journal of Entomology* **31,** 84-85.

Kajita H & Drake EF. 1969. Biology of *Apanteles chilonis* and *A. flavipes* (Hymenoptera: Braconidae), parasites of *Chilo suppressalis*. *Mushi* **42,** 163-179.

Kalshoven LGE. 1981. Pest of Crops in Indonesia. P.T. Ichtiar Baru - van Hoeve, Jakarta.

Kfir R. 1997. Natural control of the cereal stemborers *Busseola fusca* and *Chilo partellus* in South Africa. *Insect Science and its Application* **17(1),** 61-67.

Khan M & Jan A. 1994. Chemical control of sugarcane shoot borer *Chilo infuscatellus* Snellen and root borer *Emmalocera depressella* Swin. *Pakistan Sugar Journal* **8(2),** 3-5.

Khoo SG. 1986. Pest outbreaks in the tropics. *Journal of Plant Protection in the tropics* **3(1),** 13-24.

Kishore P. 1986. Studies on natural enemies of the spotted stem borer (*Chilo partellus* (Swinhoe)). *Sorghum Newsletter* **29,** 65-66.

Kumar K, Gupta SC, Mishra GP, Dwivedi GP & Sharma NN. 1987. Sugarcane pests in Bihar: Retrospect and prospect- A review. *Agricultural review* **8(2),** 59-66.

Kumar S & Kalra AN. 1965. Attack of the pink borer, *Sesamia inferens* WLK. As cane borer in Rajasthan. *Indian Sugarcane* **9,** 154-155.

Kumar S & Kaul BK. 1997. Natural enemies of rice stem borers in Kangra valley of Himachal Pradesh. *Journal of Biological Control* **11(1-2),** 69-71.

Kundu R, Saha SC, Majid MA & Abdullah M. 1994. Preliminary studies to investigate the possible effects of soil properties on sugarcane rootstock borer infestation. *International Journal of Pest Management* **40(3),** 266-269.

Kuniata LS. 1994. Pest status, biology and effective control measures of sugarcane stalk borers in the Australian, Indonesian and Pacific Island sugarcane growing regions. In: *Biology, Pest Status and Control Measure Relationships of Sugarcane Insect Pests* (eds AJM Carnegie & DE Conlong) pp. 83-96. South African Sugar Association Experiment Station, Mt Edgecombe.

Kuniata LS. 1998. Borer damage and estimation of losses caused by *Sesamia grisescens* Walker (Lepidoptera: Noctuidae) in sugarcane in Papua New Guinea. *International Journal of Pest Management* **44(2),** 93-98.

Kuniata LS. 1999. Ecology and management of the sugarcane stemborer, *Sesamia grisescens* Warren (Lepidoptera: Noctuidae) in Papua New Guinea. PhD thesis, University of Papua New Guinea.

Kuniata LS. 2000. Integrated management of sugarcane stemborers in Papua New Guinea. *Proceedings of the IV Sugarcane Entomology Workshop, ISSCT, Thailand* 37-50.

Kuniata LS & Sweet CP. 1994. Management of *Sesamia grisescens* Walker (Lep.: Noctuidae), a sugar-cane borer in Papua New Guinea. *Crop Protection* **13(7),** 488-493.
Kurian C. 1952. Description of four new and record of one known Bethyloidea (Parasitic Hymenoptera) from India. *Agra University Journal of Research* **1,** 63-72.
Leslie GW. 1994. Pest status, biology, and effective control measures of sugarcane stalk borers in Africa and surrounding island. Pp 61-73 In: AJM Caregie and DE Conlong (eds) Proceedings of the second ISSCT Sugarcane Entomology Workshop, Mount Edgecombe, South Africa.
Lewvanich A. 1981. A revision of the Old World species of *Scirpophaga* (Lepidoptera: Pyralidae). *Bulletin of the British Museum of Natural History* (Ent.) **42(4),** 185-298.
Li CS. 1970. Some aspects of the conservation of natural enemies of rice stem borers and the feasibility of harmonizing chemical and biological control of these pests in Australia. *Mushi* **44(3),** 15-23.
Li CS. 1985a. Sugarcane insect pests with special reference to mothborers in the Markham Valley, Papua New Guinea. *Mushi* **50,** 13-18.
Li Cs. 1990. Status and control of *Chilo* spp., their distribution, host range and economic importance in Oceania. *Insect Science and its application* **11,** 4/5. 535-539.
Li HK. 1993. Studies on the entomopathogenic fungi infecting reed stem borers. *Chinese Journal of Biological Control* **9(4),** 188.
Li JK. 1981. *Barathra brassicae* (L.) a new host of *Vulgichneumon leucaniae* Uchida. *Insect Knowledge* (*Kunchong Zhishi*) **18(6),** 253.
Li WJ. 1985b. Efficacy of *Chelonus munakatae* against the millet borer. *Chinese Journal of Biological Control* **1(4),** 41.
Litsinger JA 1977. *Chilo suppressalis* (Wlk.). In *Tropical Crops/Diseases, Pests and Weeds*. Paul Parey, Berlin and Hamburg. 450-452.
Liu WH, Guo MF, Han SC, Wu HH & Li LY. 1987. Inundative release of *Trichogramma nubilale* Ertle & Davis to control sugarcane borers in large areas. *Chinese Journal of Biological Control* **3(4),** 149-151.
Liu ZC, Liu JF, Wang CX, Yang WH, Liu ZC, Liu JF, Wang CX & Yang WH. 1996. The role of biological control in integrated control of sugarcane insect pests. *Biological pest control in systems of integrated pest management*. Proceedings of the International Symposium on "The use of Biological Control Agents under Integrated Pest Management" 226-230.
Liu ZC, Sun YR, Wang ZY, Liu JF, Zhang LW, Zhang QX, Dai, KJ & Gao, YG. 1985. Field release of *Trichogramma confusum* reared on artificial host eggs against sugarcane borers. *Chinese Journal of Biological Control* **3,** 2-5.
Lloyd P & Kuniata L. 2000. The control of *Sesamia* at Ramu. *Sugarcane International*, April 2000.
Macedo N, de Araujo JR & Botelho SM. 1993. Sixteen years of biological control of *Diatraea saccharalis* (Fabr.) (Lepidoptera: Pyralidae) by *Cotesia flavipes* (Cam.) (Hymenoptera: Braconidae) in the state of Sao Paulo, Brazil. *Annual Society of Entomology-Brasil* **22,** 441-448.
Mackauer M, Ehler LE & Roland J. 1990. *Critical Issues in Biological Control* Intercept, Andover, UK. 330 pp.
Macqueen A. 1969. Notes on the large moth borer, *Bathytrica truncata* (Walker). Proceedings of Queensland Society of Sugarcane Technologists. 36 conference 57-65.
Madan YP, Singh D & Singh M. 1999. Extent of damage, losses and control of sugarcane top borer, *Scirpophaga excerptalis* Walker. (Pyralidae: Lepidoptera). *Indian Sugar* **February,** 915 – 920.
Maes KVN. 1998. Pyraloidea: Crambidae, Pyralidae. pp 87 - 98. In A. Polaszek (ed.) African cereal stem borers: economic importance, taxonomy, natural enemies and control. CAB International, Wallingford, UK. 530 pp.
Mathez FC. 1972. *Chilo partellus* Swinh., *Chilo orichalcociliella* Strand (Lep., Crambidae) and *Sesamia calamistis* Hmps (Lep., Noctuidae) on maize in the Cost Province, Kenya. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* **45,** 267-289.
Meenakanit L, Sampeth T & Disthaporn S. 1988. Field trials of *Trichogramma chilotraeae* used to control *Chilo infuscatellus*. In *Trichogramma* and other egg parasites. *Colloques de l'INRA* **43,** 499-500.
Mehta OK & David H. 1980. A granulosis virus disease of sugar-cane internode borer. *Madras Agricultural Journal* **67,** 616-619.
Meijerman L & Ulenberg SA. 1996. Identification of African stemborer larvae (Lepidoptera: Noctuidae, Pyralidae) based on morphology. *Bulletin of Entomological Research* **86,** 567-578.
Mia A & Iwahashi O. 1999. Seasonal changes in infestation level of sugarcane by the pink borer, *Sesamia inferens* (Lepidoptera: Noctuidae), in relation to a parasitoid, *Cotesia flavipes* (Hymenoptera: Braconidae), on Okinawa Island. *Applied Entomology and Zoology* **34(4),** 429-434.
Miah MA, Karim MA, Khuda AK, Alam MZ & Islam MN. 1983. Control of sugarcane topshoot-borer and stem-borer. *Indian Journal of Agricultural Research* **53,** 590-592.
Mohyuddin AI. 1970. Notes on the distribution and biology of *Pediobius furvus* (Gah.) (Hym., Eulophidae), a parasite of graminaceous stem-borers. *Bulletin of Entomological Research* **59,** 681-689.
Mohyuddin AI. 1986. Report on a visit to Indonesia to advise on management of sugarcane pests. PARC-CIBC Station; Rawalpindi; Pakistan.
Mohyuddin AI. 1990. Biological control of *Chilo* spp. in maize, sorghum and millet. *Insect Science and its Application* **11(4/5),** 721-732.
Mohyuddin AI. 1991. Utilization of natural enemies for the control of insect pests of sugar-cane. *Insect Science and its Application* **12,** 1-3, 19-26; In *Proceedings of the Second International Conference on Tropical Entomology, Kenya*. 31 July-4 August 1989.
Mohyuddin AI. 1992. Implementation of integrated pest management of sugarcane pests in Pakistan. In *Integrated pest management in the Asia Pacific region*, CAB International UK. 73-84.
Mohyuddin AI, Inayatullah C & King EG. 1981. Host selection and strain occurrence in *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae) and its bearing on biological control of graminaceous stem borers (Lepidoptera: Pyralidae). *Bulletin of Entomological Research* **71,** 575-581.
Mohyuddin AI, Mushtaq M. & Attique MR. 1972. Research on bionomics, biology and control of maize stem borer and its enemies. *Annual Report* Pakistan Station, CIPC Rawalpindi.
Moutia LA. & Courtois CM. 1952. Parasites of the moth-borers of sugarcane in Mauritius. *Bulletin of Entomological Research* **43,** 325-359.
Mukunthan N. 1989. Life tables of sugarcane top borer, *Scirpophaga excerptalis* Wlk. *Insect Science and its Application* **10(3),** 269-276.
Muzaffar N & Inayatullah C. 1986. Role of salivary glands of pyralid borer larvae in host selection by *Apanteles flavipes* (Cameron) (Hym.: Braconidae). *Journal of Agricultural Research, Pakistan* **24(3),** 203-205.
Nagarkatti S & Nair KR. 1973. The influence of wild and cultivated Graminae and Cyperacae on populations of sugarcane borers and their parasites in north India. *Entomophaga* **18,** 419-430.
Nair KR. 1988. Field parasitism by *Apanteles flavipes* Cam. (Hymenoptera: Braconidae) on *Chilo partellus* Swinh. in *Coix lachryma-jobi* L. and *Chilo auricilius* (Dudgn.) in sugarcane in India. *Entomon* **13(3-4),** 283-287.
Nath DK & Hikim IS. 1978. Braconid parasites of rice yellow borer *Tryporyza incertulas* in West Bengal, India. *International Rice Research Newsletter* **3(21),** RAE 68: 3910).
Neupane FP. 1990. Status and control of *Chilo* spp. on cereal crops in southern Asia. *Insect Science and its application* **11(4/5),** 501-534.

Neupane FP, Coppel HC & Chapman RK. 1985. Bionomics of the maize borer *Chilo partellus* (Swinhoe) in Nepal. *Insect Science and its application* **6,** 547-553.

Ngi-Song AJ, Overholt WA & Ayertey JN. 1995. Suitability of African gramineous stemborer for development of *Cotesia flavipes* and *C. sesamiae* (Hymenoptera: Braconidae). *Enivironmenta Entomology* **24(4),** 978-984.

Nickel JL. 1964. Biological control of rice stem borers: A feasibility study. *Technical Bulletin* No.2, IRRI, Laguna.

Nielsen ES, Edwards ED & Rangsi TV. 1996. Checklist of the Lepidoptera of Australia *CSIRO Entomology* **(4),** 529 pp.

Nigam H. 1984. Record of *Apanteles ruficrus* Hal. (Hymenoptera: Braconidae) as a new larval parasite of sugarcane stalk borer *Chilo auricilius* Dudg. *Indian Journal of Entomology* **46,** 3, 363.

Noyes JS & Hayat M. 1994. Oriental mealybug parasitoids of the Anagyrini (Hymenoptera: Encyrtidae) with a world review of used in classical biological control and an index of parasitoids of mealybugs (Homoptera: Pseudocccidae). CAB International, Wallingford. 560 pp.

Nye IWR. 1960. The insect pests of graminaceous crops in East Africa. *Colonial Research Studies* **31,** 1-48.

Ofomata VC, Overholt WA & Egwuatu RI. 1999. Diapause termination of *Chilo partellus* (Swinhoe) and *Chilo orichalcociliellus* Strand (Lepidoptera: Pyralidae). *Insect Science and its Application* 19**(2-3),** 187-191.

Ofomata VC, Overholt WA, Lux SA, Huis A van, Egwuatu RI. 2000. Comparative studies on the fecundity, egg survival, larval feeding, and development of *Chilo partellus* and *Chilo orichalcociliellus* (Lepidoptera: Crambidae) on five grasses. *Annals of the Entomological Society of America* **93(3),** 492-499.

Ooi PA. 1998. Beyond the farmer field school: IPM and empowerment in Indonesia. *Gatekeeper series; International Institute for Environment and Development (IIED); London; UK* **78,** 16 pp.

Overholt WA. 1998. Biological control. In *African cereal stem borers: economic importance, taxonomy, natural enemies and control.* (ed.) Polaszek A. CAB International, Wallingford, UK. 530 pp.

Overholt WA, Ngi_Song AJ, Omwega CO, Kimani SN, Mbapila J, Sallam MN & Ofomata V. 1997. A review of the introduction and establishment of *Cotesia flavipes* Cameron in East Africa for biological control of cereal stemborers. *Insect Science and its Application* **17(1),** 79-88.

Pan YC & Lim GT. 1979. The biological control of sugarcane borers in Gula Perak plantation, Malaysia. *Malaysian Journal of Agriculture* **52,** 129-134.

Pandey KP, Singh RG & Singh SB. 1997a. Integrated control of top borer *Scirpophaga excerptalis* WLK in Eastern U.P. *Indian Sugar* **47(7),** 491-493.

Pandey KP, Singh RP, Saxena AK & Singh RG. 1997b. Occurrence of Gurdaspur borer, *Acigona steniellus* Hamp in eastern Uttar Pradesh. *Indian Sugar* **47(2),** 137-138.

Pandya HV. 1997. Biological control of sugarcane pests. *Cooperative Sugar* **28(9),** 684-686.

Pandya HV, Patel CB, Patel MB, Patel JR, Radadia GG, Bhatt TA & Vyas ST. 1996. Biology of sugarcane root borer. *Cooperative Sugar* **27(12),** 915-918.

Pati P & Mathur KC. 1986. *Amyotea* (*Asopus*) *malabarica* (Fabricius), a predatory bug on leaf feeding pests of rice. *Oryza* **23(3),** 200-201.

Pawar AD. 1987. Biological control of sugarcane pests in India. *Plant Protection Bulletin* **39(1&2)** 1-6.

Poinar GO, Karunakar GK & David H. 1992. *Heterorhabditis indicus* n. sp. (Rhabditida: Nematoda) from India: separation of Heterorhabditis spp. by infective juveniles. *Fundamental and Applied Nematology* **15(5),** 467-472.

Polaszek A. 1998. African cereal stem borers: economic importance, taxonomy, natural enemies and control. (ed.) CAB International, Wallingford, UK. 530 pp.

Polaszek A & Khan ZR. 1998. Host plants. In: *African Cereal Stem Borers. Economic Importance, Taxonomy, Natural Enemies and Control* (ed. A Polaszek) pp. 3-10. CAB International, Wallingford.

Polaszek A & Walker AK. 1991. The *Cotesia flavipes* species complex: Parasitoids of cereal stemborers in the tropics. *Redia* **74(3),** 335-341.

Potting RPJ, Vet LEM & Overholt WA. 1997. Geographic variation in host selection behaviour and reproductive success in the stemborer parasitoid *Cotesia flavipes* (Hymenoptera: Braconidae). *Bulletin of Entomological Research* **5,** 515-524.

Rai AK, Khan MA & Kaur S. 1999. Biological control of stalk borer, *Chilo auricilius* Dudg. In sugarcane belt of U.P. *Shashpa* **(6) 1, 59-62.**

Rajabalee MA & Governdasamy M. 1988. Host specificity and efficacy of *Apanteles flavipes* (Cam.) and *A. sesamiae* (Cam.) (Hymenoptera: Braconidae) parasites of sugar can moth borers in Mauritius. *Revue Agricole et Sucriere de l'Ile Maurice* **67(1-3),** 78-80.

Rajendran B. 1999. Field parasitization of sugarcane internode borer by egg parasitoid *Telenomus beneficiens* Zehnt. *Entomon* **24(3),** 285-287.

Rajendran B & Gopalan M. 1995. Efficacy of *Trichogramma chilonis* and *Telenomus beneficiens* on sugarcane internode borer. *Madras Agricultural Journal* **82(4),** 320-321.

Rajendran B & Hanifa AM. 1996. Efficacy of different release techniques of *Trichogramma chilonis* Ishii, parasitoid on sugarcane internode borer. *Indian Journal of Plant Protection* **24(1-2),** 98-101.

Rajendran B & Hanifa AM. 1997. Effect of insecticides on the emergence of egg parasitoid *Trichogramma chilonis* Ishii. in sugarcane field. *Cooperative Sugar* **29(1),** 27-30.

Rajendran B & Hanifa AM. 1998. Efficacy of different techniques for the release of *Trichogramma Chilonis* Ishii, parasitising sugarcane internode borer, *Chilo sacchariphagus indicus* (Kapur). *Journal of Entomological Research* **22(4),** 355-359.

Rao VP & Nagaraja H. 1969. *Sesamia* species as pests of sugarcane. In: *Pests of Sugarcane (eds JR Williams, JR Metcalfe, RW Mungomery & R Mathes*) pp. 207-223. Elsevier, Amsterdam.

Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW & Barrion AT. 1986. *Illustrated Guide to Integrated pest Management in Rice in Tropical Asia*. IRRI, Philippines, 411pp.

Rodriguez-del-Bosque LA, Browning HW & Smith JW Jr. 1990. Seasonal parasitism of corn stalkborers (Lepidoptera: Pyralidae) by indigenous and introduced parasites in Northern Mexico. *Environmental Entomology* 19**,** 393-402.

Rothschild GHL. 1970. Parasites of rice stemborers in Sarwak (Malaysian Borneo). *Entomophaga* **15,** 21-51.

Sallam MN & Allsopp PA. 2002a. *Chilo* incursion management plan - Version 1. *BSES Internal Report* PR02008.

Sallam MN & Allsopp PA. 2002b. Preparedness for borer incursion into Australia.*Australian Sugarcane* **5(6),** 5-7.

Sallam MN, Overholt WA & Kairu E. 1999. Comparative evaluation of *Cotesia flavipes* and *C. sesamiae* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidoptera: Pyralidae) in Kenya. *Bulletin of Entomological Research* **89(2),** 185-191.

Sallam MN, Overholt WA & Kairu E. 2001. Dispersal of the exotic parasitoid *Cotesia flavipes* in a new ecosystem. *Entomologia Experimentalis et Applicata* **2,** 211-217.

Samoedi D. 1989. The impacts of mass liberation of *Diatraeophaga striatalis* Towns. on population and intensity of infestation of sugarcane moth-borer, *Chilo auricilius* Dudg. in central Java. *Gula Indonesia* **15(3-4),** 46-48.

Samoedi D & Wirioatmodjo B. 1986. Population dynamics of the sugarcane top borer, Tryporyza nivella intacta Sn., and its parasitoids in Central Java, Indonesia. *ISSCT* 19**(1),** 596-603.

Sardana HR. 1993. Effect of root borer, *Emmalocera depressella* (Swinhoe) infestation on cane weight and juice quality. *Plant Protection Bulletin Faridabad* **45(4),** 26-27.

Sardana HR. 1994. New record of parasite of sugarcane root borer, *Emmalocera depressella* Swinhoe. *Bulletin of Entomology New Delhi* **35(1-2),** 150-151.

Sardana HR. 1996. Hibernation of sugarcane root borer, *Emmalocera depressella* (Swinhoe) in commercial cultivars in sub-tropics. *Agricultural Science Digest Karnal* **16(2),** 78-82.

Sardana HR. 1997a. Seasonal patterns of root borer *Emmalocera depressella* Swinhoe on sugarcane in India. *Entomon* **22(1),** 55-60.

Sardana HR. 1997b. Occurrence of entomophagous fungi on sugarcane root borer, *Emmalocera depressella* Swinhoe. *Annals of Agricultural Research* **18(1),** 104.

Sardana HR. 1998. Some observations on the biology of sugarcane root borer, *Emmalocera depressella* (Swinhoe). *Annals of Plant Protection Sciences* **6(1),** 66-69.

Sardana HR. 1999. Record of root borer, *Emmalocera depressella* on Andropogon sorghum. *Indian Journal of Entomology* **61(1),** 100-101.

Sardana HR. 2000. Integrated management of sugarcane root borer, *Emmalocera depressella* Swinhoe. *Cooperative Sugar* **32(4),** 271-274.

Sardana HR, Singh N, Tirpathi BK & Singh N. 2000. Investigations on the relationship between root borer and wilt disease of sugarcane. *Indian Journal of Entomology* **62(1),** 11-17.

Saxena H. 1992. *Spathius elaboratus* Wilkinson (Hymenoptera: Braconidae: Doryctinae) - a new larval parasite of gurdaspur borer, *Acigona steniella* (Hampson) from Uttar Pradesh. *Indian Journal of Entomology* **54(4),** 482.

Schauff ME & Lasalle J. 1998. The relevance of systematics to biological control: protecting the investment in research. pp. 425-436, in Zalucki, M.P., Drew, R.A.I., and White, G.G. (eds) Pest Management - Future Challenges. *Proceedings of the Sixth Australasian Applied Entomological Research Conference, Brisbane* Vol. 1. 560pp.

Selvaraj A, Sundara-Babu PC & Babu PC. 1994. Release of different doses of *Trichogramma* and its effect on internode borer, yield and quality of sugarcane. *Sugarcane* **2,** 22-23.

Sertkaya E & Kornosor S. 1994. Distribution and natural parasitism of *Platytelenomus busseolae* (Gahan) (Hymenoptera: Scelionidae), the egg parasitoid of corn stalk borer *Sesamia nonagrioides* Lef. (Lepidoptera: Noctuidae) in Cukurova. *Turkiye III. Biyolojik Mucadele Kongresi Bildirileer* 565-574.

Shah NK & Garg DK. 1986. Pest complex of ragi *Eleusine coracana* G. in hills of Uttar Pradesh. *Indian Journal of Entomology* **48(1),** 116-119.

Shahjahan M & Talukder FA. 1995. Influence of major pests of rice on yield in Bangladesh. *Pakistan Journal of Scientific and Industrial Research* **38(2),** 88-90.

Shami S & Mohyuddin AI. 1992. Studies on host plant preference of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) an important parasitoid of graminaceous stalk borers. *Pakistan Journal of Zoology* **24(4),** 313-316.

Sharma AK, Saxena JD & Subba Rao BR. 1966. A catalogue of the hymenopterous and dipterous parasites of *Chilo zonellus* (Swinhoe) (Crambidae: Lepidoptera). *Indian Journal of Entomology* **28,** 510-542.

Shenhmar M & Brar KS. 1996a. Evaluation of parasitoids for the management of *Chilo infuscatellus* (Snellen) and *Scirpophaga excerptalis* (Fabricius) on sugarcane in Punjab. *Indian Sugar* May 1996, 121- 123.

Shenhmar M & Brar KS. 1996b. Efficacy of two strains of *Cotesia flavipes* (Cameron) for the control of sugarcane borers. *Indian Sugar* **45(11),** 877-879.

Shenhmar M & Varma GC. 1988. Some observations on biology and rearing technique of *Rhaconotus signipennis* (Walker) (Braconidae: Hymenoptera). *Journal of Research, Punjab Agricultural University* **25(1),** 67-69.

Shenhmar M, Verma GC & Brar KS. 1990. Studies on the establishment of *Allorhogas pyralophagus* Marsh. (Braconidae: Hymenoptera) on sugarcane borers in the Punjab. *Journal of Insect Science* **3(1),** 53-56.

Shojai M, Abbas PH, Nasrollahi A & Labbafi Y. 1995. Technology and biocenotic aspects of integrated biocontrol of corn stem borer: *Sesamia cretica* Led. (Lep. Noctuidae). *Journal of Agricultural Sciences* Islamic Azad University **1(2),** 5-32.

Simmond FJ. 1969. Report of work carried out during 1969. *Commonwealth Institute of Biological Control* 103 pp.

Singh B, Dhaliwal JS, Battu GS & Atwal AS. 1975. Population studies on the maize-borer *Chilo partellus* (Swinhoe) in the Punjab. III. Role of parasitization by *Apanteles flavipes* (Cameron) in the population build-up. *Indian Journal of Ecology* **2,**115-124.

Singh M, Chhiliar BS & Madan YP. 1996. Biology of sugarcane root borer *Emmalocera depressella* Swinhoe. *Indian Sugar* **45,** 12.

Singhal RC, Gupta MR & Narayan D. 2001. Eco-friendly approach for minimising populations of sugarcane stalk borer (*Chilo auricilius*) in the Tarai Belt of Uttar Pradesh, India. *ISSCT* **24,** 374-377.

Sivasankaran P, Easwaramoorthy S & David H. 1990. Pathogenicity and host range of *Beauveria* nr. *bassiana*, a fungal pathogen of *Chilo infuscatellus* Snellen. *Journal of Biological Control* **4(1),** 48-51.

Smith JW Jr. 1994. Publications associated with stalk borers and Texas. In: *Biology, Pest Status and Control Measure Relationships of Sugarcane Insect Pests* (eds AJM Carnegie & DE Conlong) pp. 75-82. South African Sugar Association Experiment Station, Mt Edgecombe.

Smith JW JR & Wiedenmann RN. 1997. Foraging strategies of stemborer parasites and their application to biological control. *Insect science and its Application* **17(1),** 37-49.

Smith JW Jr, Wiedenmann, RN & Overholt WA. 1993. Parasites of lepidopteran stemborers of tropical gramineous plants. *ICIPE Science Press*, Nairobi, 89pp.

So DP & Okada M. 1989. Cross infectivity of nuclear polyhedrosis viruses to the common armyworm, *Pseudaletia separata*. *Korean Journal of Applied Entomology* **28(1),** 10-15.

Soliman M & Mihm JA. 1997. Corn borers affecting maize in Egypt. In Insect resistant maize: recent advances and utilization. *Proceedings of International Symposium, International Maize and Wheat Improvement Center*, 27 November-3 December 1994. 276-278.

Sonan J. 1929. A few Host-Known Ichneumonidae found in Formosa. *Transactions of the Natural History Society of Formosa* **19,** 415-425.

Srikanth J, Easwaramoorthy S, Shanmugasundaram M & Kumar R. 1999. Seasonal fluctuations of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) parasitism in borers of sorghum and sugarcane in southern India. *Insect Science and its Application* 19**(1),** 65-74.

Suasa-ard W. 2000. *Chilo tumidicostalis* (Hampson) (Lepidoptera: Pyralidae) and its natural enemies in Thailand. *Proceedings of the IV Sugarcane Entomology Workshop, ISSCT, Thailand* 10-16.

Suasa-ard W. & Charernsom K. 1995. Natural enemy complex of sugarcane moth borers in Thailand. *ISSCT* **21,** CCCLIV, Poster paper.

Subba Rao BR & Chawla SS. 1964. A catalogue of hymenopterous parasites of rice stem borers. *Indian Journal of Entomology* **26,** 332-344.

Subba Rao BR, Singh RN, Saxena JD, & Sharma AK. 1969. Bionomics *of Apanteles flavipes* (Cameron) a parasite of *Chilo zonellus* (Swinhoe) at Delhi with special reference to the mode of overwintering of the parasite. *Indian Journal of Entomology* **31,** 7-12.

Sukhani TR. 1986. Insect pest management in sorghum. *Plant Protection Bulletin* 38 **(1-4),** 57-62.

Sunaryo & Suryanto SJ. 1986. Augmentation of local and introduction of Thailand strain of *Cotesia flavipes* (Cam.) in Gunung Madu Plantations, Lampung, Indonesia*. Proceedings of the Annual Convention, Pakistan Society of Sugar Technologists* (22nd) 153-159.

Takano S. 1934. Hymenopterous parasites of lepidopterous pests of sugarcane in Formosa and their bibliography. *Journal of Formosa Sugar Plant Association* **11,** 454-466.

Tams WHT. 1932. New species of African Heterocera. *Entomologist* **65,** 1241-1249

Tams WHT & Bowden J. 1953. A revision of the African species of *Sesamia* Guenee and related genera (Lepidoptera – Agrotidae). *Bulletin of Entomological Research* **43,** 645-678.

Tan SW & Koh HL. 1980. Integrated control of sugarcane borers in the Northwest Peninsula Malaysia and Lampung, Sumatra, Indonesia. *ISSCT* **17(2),** 1693-1703.

Taneja SL & Nwanze KF. 1989. Assessment of yield loss of sorghum and pearl millet due to stem borer damage. In International Workshop on Sorghum Stem Borers. 17-20 Nov 1987, ICRISAT Center, Patancheru, India. pp. 95-104.

Tanwar RK. 1990. Biology of *Elasmus zehntneri* Ferriere, an ecto larval parasitoid of the sugarcane top borer, *Scirpophaga excerptalis* Walker. *Journal of Biological Control* **4(2),** 120-121.

Tanwar RK & Varma A. 1997. *Scirpophaga excerptalis* Walker infestation in relation to its natural parasitoids and sugarcane cultivars in eastern Uttar Pradesh. *Uttar Pradesh Journal of Zoology* **17(1),** 33-37.

Teetes GL, Seshu Reddy KV, Leuschner K & house LR. 1983. Sorghum insect identification handbook. *Information Bulletin* (12). India: International Crops Research Institute for the Semi-Arid tropics. 124 pp.

Temerak SA & Negm AA. 1979. Impact and differential effect of certain biomortality factors on the eggs and newly-hatched larvae of the pink borer *Sesamia cretica* Led. (Lep., Noctuidae) on two sugarcane varieties. *Zeitschrift für angewandte Entomologie* 88, 313-318.

Tuhan NC & Pawar AD. 1983. Life history, host suitability and effectiveness of *Trichogramma chilonis* (Ishii) for controlling sugarcane borers in the Punjab. *Journal of Advanced Zoology* **4(2),** 71-76.

Tyagi MP & Sharma VK. 1989. Biology of pink stemborer, *Sesamia inferens* Walker on different host plants. *Bulletin of Entomology-New Delhi* **27(2),** 191.

Ubandi H & Sunaryo. 1986. Introduction of *Allorhogas pyralophagus* Marsh (Braconidae) in Lampung (Indonesia) with preliminary notes on its biology. *Proceedings of the International Society of Sugarcane Technologists* 19**,(1)** 563-567.

Ubandi H, Sunaryo, Suryanto SJ, Suroyo & Mohyuddin AI. 1988. Notes on biology of *Elasmus zehntneri* Ferriere and its augmentation for controlling top borer *Scirpophaga nivella* (F.) at Gunung Madu Plantations, Lampung, Sumatra, Indonesia*. Proceedings of the Annual Convention, Pakistan Society of Sugar Technologists* **23,** 243-254.

van Hamburg H & Hassell MP. 1984. Density dependence and the augmentative release of egg parasitoids against graminaceous stalk borers. *Ecological Entomology* **9,** 101-108.

van Verden G & Ahmadzabidi AL. 1986. Pests of Rice and their Natural Enemies in Peninsular Malaysia. PUDOC, Wageningen.

Varma A & Saxena H. 1989. Field recovery of an exotic parasite, *Allorhogas pyralophagus* Marsh against sorghum borer *Chilo partellus* Swinhoe. *Indian Journal of Plant Protection* **17,** 101-102.

Vinson J. 1942. Biological control of *Diatraea mauriciella* in Mauritius. I. Investigation in Cylon in 1939. *Bulletin of Entomological Research* **33,** 45.

Wang GR, Liu ZC, Wang ZY, Sun SR, Jiang QR, Liang YF, Zhen Q & Zheng JC. 1985. Studies on the dominant species of *Trichogramma* in sugarcane fields in Guangdong Province and the effect of releasing exotic species. *Natural Enemies of Insects, Kunchong Tiandi* **7(1),** 13-18.

Way MJ & Turner PET. 1999. The spotted sugarcane borer, *Chilo sacchariphagus* (Lepidoptera: Pyralidae: Crambinae), in Mozambique. *Proceedings of the South African Sugarcane Technologists Association* **73,** 112-113.

Wen CS & Sun CX. 1989. Notes on Microsporidia (Protozoa Microspora) from the silkworm *Bombyx mori* L. and the sugarcane stem borer *Chilo infuscatellus* Snella in China. *Scientia Agricultura Sinica* **22(2),** 15-19.

Wen JZ & Sun CX. 1988. Two new species of *Nosema* (Microspora: Nosematidae). *Acta Zootaxonomica Sinica* **13(2),** 105-111.

Wiedenmann RN & Smith JW JR. 1997. Novel association and importation biological control: The need for ecological and physiological equivalencies. *Insect science and its Application* **17(1),** 51-60.

Williams JR. 1978. An annotated check list of the invertebrates (insects, mites, nematodes) of sugarcane in Mauritius. *Occasional paper* No. 31. Mauritius Sugar Industry Research institute 22pp.

Williams JR. 1983. The sugarcane stem borer (*Chilo sacchariphagus*) in Mauritius. *Revue Agricole et Sucriere de l'Ile Maurice* **62,** 5-23.

Young GR. 1982. Recent work on biological control in Papua New Guinea and some suggestions for the future. *Tropical Pest Management* **28(2),** 107-114.

Young GR & Kuniata LS. 1992. Life history and Biology of *Sesamia grisescens* Walker (Lepidoptera: Noctuidae), a sugarcane borer in Papua New Guinea. *Journal of the Australian Entomological Society* **31,** 199-203.

Zangheri S & Furlan L. 1998. Outbreak of *Angustalius malacellus* on maize in Veneto. *Informatore Fitopatologico* **48(11),** 29-31.

Zhang ZQ. 1986. A study on biological and ecological characteristics of *Apanteles ruficrus* Haliday. *Natural Enemies of Insects* **8(2),** 84-89,97.