Hypsipyla Shoot Borers in Meliaceae

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CONTENTS

Foreword

It has been a most welcome and opportune initiative of CSIRO Entomology and the Queensland Forestry Research Institute (QFRI) to organise an International Workshop on Hypsipyla which was hosted by the Forestry Department of Sri Lanka and supported financially by ACIAR, DFID, AusAID and RIRDC. The papers presented at the meeting and now incorporated in these Proceedings reflect both the current 'state of the art' and the involvement of a great number of national and international institutions and organisations in research on the shoot borers of the Meliaceae. No less than 35 participants from 16 countries, representing 25 institutions and organisations have been involved in the workshop.

The organisers of the workshop are to be congratulated for the intercontinental and participatory approach of the meeting, which provided a binding element in the search for a common solution to a common problem. Hopefully, these contacts can be maintained and perhaps even expanded into effective international collaboration. As it has been more than 20 years since the First Symposium on Integrated Control of *Hypsipyla* was held in Turrialba, Costa Rica, by the Inter-American Working Group on *Hypsipyla*, the Kandy workshop also represents the end of a long period of discontinuity in major international co-operative research on the relationship between the valuable Meliaceae and their most intractable insect pest *Hypsipyla* spp.

The current international need to find a solution to the age-old shoot borer problem is given impetus by the rapid erosion of genetic sources of the Meliaceae in most of the continents. In 1992, during the Earth Summit at Rio de Janeiro, ecologists and biologists predicted that 10–20% of the earth's estimated 10 million species of plants and animals would have become extinct by the year 2020. Of these, 50% were likely to be lost due to disappearing tropical rainforests.

Meanwhile, *Swietenia humilis* and *S. mahagoni* have been listed on Appendix 2 of the Convention on International Trade in Endangered Species (CITES), while the inclusion on Appendix 2 of *S. macrophylla*, currently listed on Appendix 3, was considered. The inclusion of the mahoganies on this list obliges timber companies to formalise the export from the countries of origin and forces the governments of exporting countries to warrant that the species is still adequately stocked in the forests. Trade in these species is not prohibited. However, in a number of Western European countries, a discussion is currently taking place to limit the import of tropical timber species to only those that are produced on a sustained yield basis. That would clearly pose a problem with regard to species of Meliaceae such as the cedars and mahoganies for which, notwithstanding all efforts in the past, no viable silvicultural system exists yet in the countries of origin, not even in Australia.

Fortunately, CSIRO Entomology and the QFRI are taking up the challenge to find a solution for the shoot borer problem in a multidisciplinary approach. A stimulating interaction between disciplines, in addition to motivated Ph.D candidates and post-graduate students, forest nursery facilities, experimental plantation areas and last but not least a mass rearing program, were a few of the key factors that resulted in a high research productivity of the Working Group on *Hypsipyla* at CATIE in Turrialba, Costa Rica. It was most encouraging to learn that research on the shoot borer has again been taken up at CATIE.

Among the important research subjects that remained largely undeveloped after the research in the 1970s and 1980s were silviculture and ecology of the Meliaceae, i.e. soil and site selection, silvicultural systems of line or group plantings in existing wet and dry forests and the degree of heterogeneity of mixed plantations. To determine the place of the Meliaceae within the complex environment of the tropical forest, with its multiple interdependent biological networks, requires long-term research and consequently substantial funding. Researchers as well as funding agencies experience that prospect as a barrier. To pass that barrier the co-ordinated support of several development agencies and sponsors, as well as the close collaboration of Forest Services, might be necessary.

Indigenous Parasitoids and Exotic Introductions for the Control of *Hypsipyla grandella* (Zeller) (Lepidoptera: Pyralidae) in Latin America

H. Blanco-Metzler[1], C. Vargas[2] and C. Hauxwell[3]

Abstract

Hypsipyla grandella (Zeller) is the most important insect pest of the Meliaceae in the Neotropics. This paper reviews the information on *H. grandella* parasitoids in Latin America and the Caribbean. Preliminary data on the parasitoid complex in Turrialba, Costa Rica, are presented, where apparent parasitisation of *H. grandella* during 1995–1996 reached 36%. The lowest level of parasitisation occurred during the dry season. The parasitoid *Apanteles* sp. (= *Hypomicrogaster hypsipylae* de Santis?) (Hymenoptera: Braconidae) was the most abundant larval parasitoid with a mean of 22 parasitoids per parasitised larva and a sex ratio of 3:1 females to males. *Brachymeria conica* Ashmead (Hymenoptera: Chalcididae) was found parasitising pupae, but at low frequency.

THE MAHOGANY shoot borer *Hypsipyla grandella* (Zeller) (Lepidoptera: Pyralidae) is the overriding detrimental factor affecting the establishment of plantations of Spanish cedar (*Cedrela* spp.) mahogany (*Swietenia* spp.) and 'cedro macho' or crabwood (*Carapa guianensis* Aubl.) in the Neotropics. Larvae feed inside the young shoot, frequently killing it, resulting in forking and retarded growth of the trees and thus reduced economic yields of timber. Previous attempts at biological control of *H. grandella* have not been successful in reducing damage (Newton et al. 1993).

The present paper reviews available information on parasitoids of *H. grandella* in Costa Rica and other countries of Latin America and Trinidad. It also includes preliminary results on the fluctuation of indigenous parasitoid populations in Turrialba, Costa Rica.

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Occurrence of *Hypsipyla* Parasitoids in Latin America

For any biological control program to be implemented, a thorough search for and accurate identification of existing natural enemies and potential biological control agents must be made. In Latin America, there have been few formal studies of parasitoids of *H. grandella* that can provide information of their identity, distribution and abundance. The existing information is mainly from the Centro Agronomico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica. A survey of natural enemies affecting *H. grandella* in Costa Rica was initiated in 1970. Five *Trichogramma* species (Hymenoptera: Trichogrammatoidea) were found to parasitise the eggs of *H. grandella*, while three species of Braconidae and one species of Chalcididae were found to parasitise the larvae and/or pupae (Grijpma 1973). Hidalgo Salvatieri and Madrigal Sanches (1970) recorded 10% to 40% of eggs of *H. grandella* parasitised by an unidentified *Trichogramma* sp. Bennett (1976a) reported similar species parasitising *H. grandella* in Belize. Table 1 lists indigenous parasitoids of *H. grandella* reported in the literature.

Percentage parasitisation of eggs in the field can be as high as 40% (Hidalgo Salvatieri and Madrigal Sanches 1970). Grijpma (1972) reported a high

Table 1. Parasitoid species reared from *Hypsipyla grandella* (except where indicated otherwise) in Latin America.

Parasitoid	Country	References
Egg parasitoids		
Trichogrammatidae		
Trichogramma spp.	Costa Rica, Peru	Hidalgo-Salvatierri and Madrigal Sánchez 1970, Yamazaki et al. 1990
T. beckeri (Nagarkatti)	Costa Rica	Nagarkatti 1973
T. bennetti (Nagarkatti) (on *H. ferrealis* Hampson)	Trinidad	Nagaraja and Nagarkatti 1973
T. fasciatum (Perkins)	Costa Rica	Grijpma 1973; Nagarkatti and Nagaraja 1977
Trichogrammatoidea hypsipylae (Nagaraja)	Costa Rica, Trinidad	Nagaraja, 1978
T. pretiosum (Riley)	Costa Rica, Mexico	Grijpma 1972, 1973; Nagarkatti 1973
T. near *pretiosum*	Costa Rica	Grijpma 1972; Nagarkatti 1973
T. semifumatum (Perkins)	Costa Rica	Grijpma 1972; Nagarkatti 1973
Larval parasitoids		
Braconidae		
Agathis sp.	Belize	Bennett 1976a
Apanteles spp.	Trinidad	Bennett and Yaseen 1972; Yaseen 1984
Apanteles sp. (= *Hypomicrogaster hypsipylae* De Santis?)	Costa Rica	This paper
Apanteles sp. (ater group)	Belize	Bennett 1976a
Apanteles sp. (laevigatus group)	Belize	Bennett 1976a
Bassus sp.	Costa Rica	This paper
Bracon sp.	Peru	Yamazaki et al. 1990
Bracon chontalensis Cameron	Belize, Costa Rica, Trinidad	Bennett 1976a; Bennett and Yaseen 1972
Hormius sp.	Trinidad	Bennett and Yaseen 1972; Yaseen 1984.
Hypomicrogaster hypsipylae De Santis	Brazil, Costa Rica	De Santis 1972 Bennett 1976a; Nagarkatti and Nagaraja 1977
Iphialtes sp.	Trinidad	Bennett and Yaseen 1972
Myosoma sp. (= *B. chontalensis*?)	Costa Rica	This paper
Unknown (Microgastrinae)	Costa Rica	This paper
Ichneumonidae		
Eiphosoma sp.	Belize	Bennett 1976a
Chalcidoidae		
Indet sp.	Belize	Bennett 1976a
Tachinidae		
Chrysodoria sp.	Trinidad	Bennett and Yaseen 1972; Yaseen 1984.
Larval-pupal parasitoids		
Tachinidae		
Metapiops mirabilis Townsend	Trinidad, Belize	Bennett and Yaseen 1972; Bennett 1976a
Pupal parasitoids		
Chalcididae		
Brachymeria conica (Ashmead)	Costa Rica, Trinidad.	Bennett 1976b; Grijpma 1973.

incidence of *Trichogramma* species parasitising eggs in the field and 10% parasitisation of eggs by *Trichogramma* sp. was reported in the Peruvian Amazon (Yamazaki et al. 1990). Bennet (1976a) gives approximate levels of parasitism of larvae in Belize of 13.8% and 24.5% in 1968 and 1969 respectively. Limited mortality due to parasitisation of larvae by *Bracon* sp. (Hymenoptera: Braconidae) was reported in Peru. Parasites of pupae of *H. grandella* are, however, rare (Bennett 1976a, b).

Population Fluctuation of Parasitoids of *H. grandella* in Turrialba, Costa Rica

The aim of this study was to determine the presence of *H. grandella* larvae and pupae of *H. grandella* and to record fluctuations in parasitoid abundance. Although egg parasitism has been reported (Table 1), the study focused on larval parasitoids due to the difficulties in finding un-hatched eggs in the field. Preliminary results are presented.

Materials and Methods

Field work was carried out at CATIE, at elevations ranging from 600 to 650 m. The mean annual rainfall in the area is 2600 mm, mean temperature is 21 °C, and mean relative humidity is approximately 80%. From July 1995 to February 1996, samples of larvae were collected from *Swietenia macrophylla* King saplings at three different sites within CATIE. From March 1996, samples were collected from 20 trees aged 18 months in the nursery at CATIE.

Damaged shoots were harvested from trees each month. Shoots were examined in the laboratory and the number of larvae and their instar recorded. The larvae were incubated individually on fresh leaves and stems changed every four days in petri-dishes or on artificial diet (Hauxwell 1997) until emergence of either the adult moth or a parasitoid. Percentage parasitism was estimated as the number of larvae parasitised as a proportion of the total number of larvae collected.

Results and Discussion

Five species of hymenopteran parasitoids were recovered from larvae and pupae (Table 2). Four species of Braconidae and one species of Chalcididae emerged from larvae and pupae between 1995 and 1996. There is some confusion regarding the identity of two of the parasitoids. *Apanteles* sp. and *Myosoma* sp. were identified by Alejandro Valerio and Paul Hanson, University of Costa Rica, but are normally referred to as *Hypomicrogaster hypsipylae* De Santis and *Bracon chontalensis* Cameron respectively. The larval parasitoid complex was dominated by *Myosoma* sp. (= *B. chontalensis*?) during 1995 and by *Apanteles* sp. (= *H. hypsipylae*?) during 1996. *Apanteles* sp. (= *H. hypsipylae*?), *Myosoma* sp. (= *B. chontalensis*?) and the pupal parasitoid *Brachymeria conica* (Chalcididae) occurred in both years, while *Bassus* sp. and an unknown braconid occurred only during the first year.

Table 2. Parasitisation of *Hypsipyla grandella* at CATIE, Turrialba, Costa Rica, during 1995 and 1996.

	No. of parasitised larvae reported	
	1995	1996
Larval parasitoids		
Braconidae		
Apanteles sp. (Microgastrinae) = *H. hypsipylae*?	4	17
Unknown (Microgastrinae)	2	0
Myosoma sp. (Braconinae) = *B. chontalensis*?	13	4
Bassus sp. (Agathidinae)	1	0
Pupal parasitoids		
Chalcididae		
Brachymeria conica	3	2

Apanteles sp. (= *H. hypsipylae*?) was the most abundant of the parasitoid species, both in terms of the number of shoot borer larvae parasitised and the number of parasitoids that emerged. *H. hypsipylae* is a gregarious endoparasitoid; i.e. the female lays all eggs at one time (Shaw 1995). Twenty seven larvae parasitised by *Apanteles* sp. were examined in the laboratory, from which 598 parasitoids emerged, with a range between 1 and 75 and a mean of 22 ± 16 (S.D.) wasps per larva.

De Santis (1972) reported that all the adult *H. hypsipylae* which emerged from *H. grandella* were females. In this study, 12 *H. grandella* larvae parasitised by *Apanteles* sp. were taken at random and the sex of their parasitoids determined. Not all were female, although significantly more female than male parasitoids adults were reared (χ^2 = 85.11; df = 1; P <0.001), with a sex ratio of 3:1.

The percentage parasitisation during each year of sampling is presented in Figure 1. The highest degrees of parasitism were found in August 1995 and May 1996, two to three months after the onset of rains and production of shoots. Shoots were plentiful

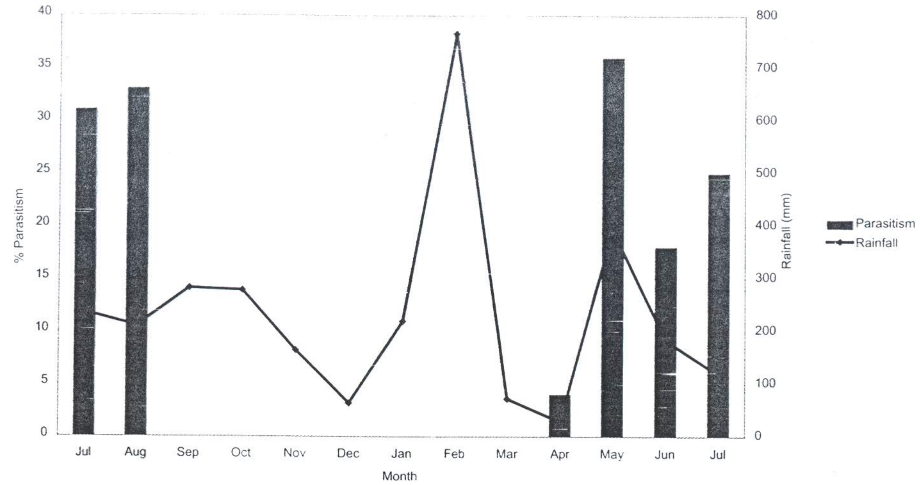

Figure 1. Percentage parasitisation of *Hypsipyla grandella* and rainfall at Turrialba, Costa Rica, 1995–1996.

early in 1996 following exceptionally heavy rain in February in the wake of hurricane Bertha and larvae were recovered, but none were parasitised. Thus, it appears that percentage parasitisation in 1996 lagged behind an increase in the *H. grandella* population. Temperature did not seem to have any influence on the percentage of parasitisation.

Discussion

This is the first survey of the incidence of parasitisation conducted at frequent intervals through a full year in Central America. The results suggest a relationship between percentage parasitism and rainfall, with percentage parasitisation rising following the start of rains. Similarly, Bennett (1976a) reports seasonal variation in shoots and a decrease in attack in Trinidad, the Lesser Antilles and Belize. Results from previous studies suggest that *H. grandella* infestation in Turrialba also peaked during the period when new shoots were available (Newton et al. 1993). Shoot borer activity is reported to increase after the dry season when the first rains begin, and incidence of damage corresponds closely to precipitation (Grijpma and Gara 1970: Howard 1991; Tillmans 1964; Yamazaki et al. 1990). Grijpma and Gara (1970) reported an increase in *Hypsipyla* flight activity 3–4 days after rain, when the moths are attracted to the new foliage produced following the onset of rain (Gara et al. 1973)

The increase in available host insects following the increase in shoots may in turn support an increase in the parasitoid population. These results suggest that there may be a lag between onset of *H. grandella* attack and the onset of parasitisation. Repeat studies relating parasitism to incidence and severity of insect attack and shoot availability are required to confirm this observation.

Parasitisation can cause high levels of mortality in *H. grandella* in Latin America. Egg parasitisation in the region is usually reported to be of the order of 10%, although it may reach up to 40% (Hidalgo Salvatieri and Madrigal Sanches 1970; Yamazaki et al. 1990). These data suggest that more than one third of larvae can be parasitised in the field. Similarly, Bennett (1976a) reported approximately 13.8% and 24.5% parasitisation of *H. grandella* larvae in Belize during 1968 and 1969.

In this survey, four different species of parasitoid, mostly Braconids, were associated with *H. grandella* larvae and were relatively common. The parasitoids which were most abundant in the *H. grandella* population were *Apanteles* sp. (= *H. hypsipylae*?) and *Myosoma* sp. (= *B. chontalensis*?). *B. conica* (Chalcididae), which is a parasitoid of several species and has a broad geographical range from Texas to Brazil and Trinidad (Grijpma 1973), was found to parasitise pupae.

Pupal parasitism was rare and no egg-larval parasitoids were found. Similarly, low levels of parasitisation of pupae and the absence of egg-larval parasitoids in Belize were reported by Bennett (1976a, b). This is in contrast to results of surveys of parasitisation of *H. robusta* Moore in India, where pupal parasitisation can reach 66% and parasitisation of egg-larvae can reach 27% (Bennett 1976b).

Bennett (1976a) suggested that parasitoids keep the *H. grandella* population in partial check, and that even a small increase in mortality levels might reduce populations to an acceptable level. In contrast to many other agents of control, parasitoids can locate a cryptic host by olfactory cues, and have been observed drumming on the shoot to locate larvae in the tunnel (Yamazaki et al. 1990). Yet introductions of parasitoids of *H. robusta* have been conspicuously unsuccessful (Newton et al. 1993). During 1969 to 1982, a program which aimed to introduce *H. robusta* parasitoids from India into Belize and the Lesser Antilles was established by the International Institute of Biological Control (IIBC), and is reviewed in these Proceedings by Sands and Murphy. Recovery surveys showed, however, that only *Trichogrammatoidea robusta* Nagaraja appeared to have established, and that only in Trinidad (Bennett and Yaseen 1972; Cock 1985). In Belize and the other islands of the Lesser Antilles, no introduced species were recovered following release.

In these releases, consignments of insects for release were delayed and many were dead before arrival in Belize. Furthermore, the releases were conducted in November, a time when there were few *H. grandella* in the field. It seems probable that most of the released parasitoids perished before they could find a suitable host (Bennett 1976a). Bennett (1976b) suggested that introductions might fail for several reasons:

- failure of parasitoids specific to *H. robusta* to survive in *H. grandella*;
- failure of an introduced parasitoid to survive under the different climatic conditions of the release area;
- failure of an introduced parasitoid to survive during the dry season when host larvae are scarce;
- release of too few individuals, and/or
- release of inbred or otherwise genetically inferior stock.

Furthermore, the parasitoids released in Belize were reared in Trinidad on *Corcyra cephalonica* (Stainton) (Bennett 1976c; Yaseen and Bennett 1972). Newton et al. (1993) suggested that rearing the parasitoids in this alternative host might have impaired the detection of olfactory cues required to locate *H. grandella* in the field. Thus, rearing these parasitoids on *H. grandella* might improve location, particularly when the *H. grandella* are reared on plant material from Neotropical Meliaceae (Bennett 1976c). Large-scale rearing of *H. grandella* has been successful in Costa Rica (Sterringa 1976; Hauxwell 1997). Grijpma (1972) successfully reared *Trichogrammatoidea semifumatum* (Perkins) in the laboratory over several months and generations in eggs of *H. grandella*. He noted that if the egg was 39 hours old or less when parasitised, then all eggs failed to hatch, but that if parasitised between 50 and 62 hours, 30% of eggs would hatch. Each egg contained on average 2 to 3 parasitoids. Rearing of parasitoids for release against *Hypsipyla* species is discussed in Bennett (1976c) and Yaseen and Bennett (1972).

Some control might be achieved by augmentative releases of indigenous parasitoids. These results suggest that there may be a lag between onset of *H. grandella* attack and the rise in parasitisation. Thus, plants may suffer economic levels of damage before the parasitoid populations can build up sufficiently to reduce the pest. Thus an early release of a parasitoid might be effective: e.g. immediately following the first rains. Bennett (1976b) recommended inundative release of *Trichogramma* sp., a technique that has successfully reduced levels of damages in other cryptic-feeding pest systems. For example, mass release of *T. dendrolini* Matsuma for the control of the codling moth (*Cydia pomonella* L.) and the summer fruit tortrix moth (*Adoxophyes orana* F. R.) in apple orchards was reported to reduce damage by *C. pomonella* by 61% and by *A. orana* by 73% (Hassan et al. 1988).

Augmentation of abundance of one or several of the five native *Trichogramma* species would seem worthy of further investigation. The only reported attempt at such a release, however, was not successful: Orozco Ramos (1989) evaluated the parasitism of *H. grandella* eggs following liberation of the indigenous *Trichogramma pretiosum* Riley in a 50 ha plantation of *Cedrela* sp. and *Swietenia* sp. in Tabasco, Mexico. Five batches each of 1.6 million wasps were released at fortnight intervals. Sampling was undertaken four days after the third and fifth liberation, but only a single parasitised egg was recovered.

Meliaceae need to be protected from shoot borer attack for several years until the tree reaches a commercial height. Thus repeated augmentative release may not be feasible on economic grounds. Furthermore, it may be that the level of attack that can be tolerated commercially may be very low, perhaps as low as one attack per tree. In this case, the numbers of *H. grandella* larvae that can be tolerated may be so low that host-specific parasitoids could not persist. An economic threshold for *H. grandella* attack has not yet been determined but would be useful in assessment of the potential of biological control.

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