Infestation of Meliaceous Trees by the Mahogany Shoot Borer in Plantation Areas of the Peruvian Amazon

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Abstract

A large number of tree species planted on degraded forest lands in the tropics are presently being threatened by many forest pests and diseases. Tree damage occurs not only on monocultural but also on various types of plantations over vast areas. The mahogany shoot borer, *Hypsipyla grandella* Zeller, is the most harmful insect pest against meliaceous species in South America. Field surveys on tree damage conducted in the plantation areas of the Peruvian Amazon revealed that both Spanish ceder (*Cedrela odorata*) and mahogany (*Swietenia macrophylla*) were heavily infested by *H. grandella*, particularly, in line planting and opened areas within three years after planting. Other planting trials, such as mixed planting or planting under the canopy of surrounding trees, were also unsuccessful in most cases. Trees under low light intensity, including those in natural regeneration, have escaped from initial attacks of the insect pest for a relatively longer period of time, though the tree growth was reduced. Frequent sprouting (3 to 5.5 times a year) induced repeated attacks of the insect, resulting in regeneration failure of the tree. However, since the insect density is reduced in the dry season and that the adult moth seldom flies at a height of more than 8 m above ground, the development of effective control measures may become possible.

Introduction

The genus, *Hypsipyla*, a mahogany shoot borer, is well known as the most serious insect pest against meliaceous tree species in the tropical and subtropical regions of the world. Among 10 species, *Hypsipyla grandella* and *H. robusta* are most destructive in the New World (Central and Latin America) and the Old World (Asia and Africa), respectively (Fig. 1). *H. grandella* attacks all the Latin American Meliaceae, particularly, the *Cedrela* and *Swietenia* species (Table 1). Larvae bore into and hollow out branches, stems, cones and seeds. The damage leads mainly to the interruption of growth or branching off in all directions caused by the repeated attacks on the terminal shoots of the young trees.

In the Peruvian Amazon areas since a large number of species of useful trees including *Cedrela* and *Swietenia* have been lost for decades due to selective logging and shifting cultivation, there has been a frowning awareness about the need for promoting the rehabilitation and sustainable use of such valuable tree resources since the early 1980s (Matsui, 1986; Kobayashi *et al*., 1986). Consequently, a research project for the development of afforestation techniques was initiated in 1982 by the National Institute of Forestry and Zoology, Peru and the Japan International Cooperation Agency, Japan. Since then, *Cedrela odorata* (Spanish cedar) and *Swietenia macrophylla* (Mahogany) have been planted in large numbers in various ways. However, both species of trees have been heavily infested with *H. grandella* within two years after planting.

The objectives of this study are to analyse the overall aspects of *H. grandella* infestation in plantation

Presented at the International Symposium on "the Rehabilitation of Degraded Forest Lands in the Tropics"-Technical Approach, Tsukuba, Ibaraki, Japan, 17 September 1992, held by Tropical Agriculture Research Center (TARC).

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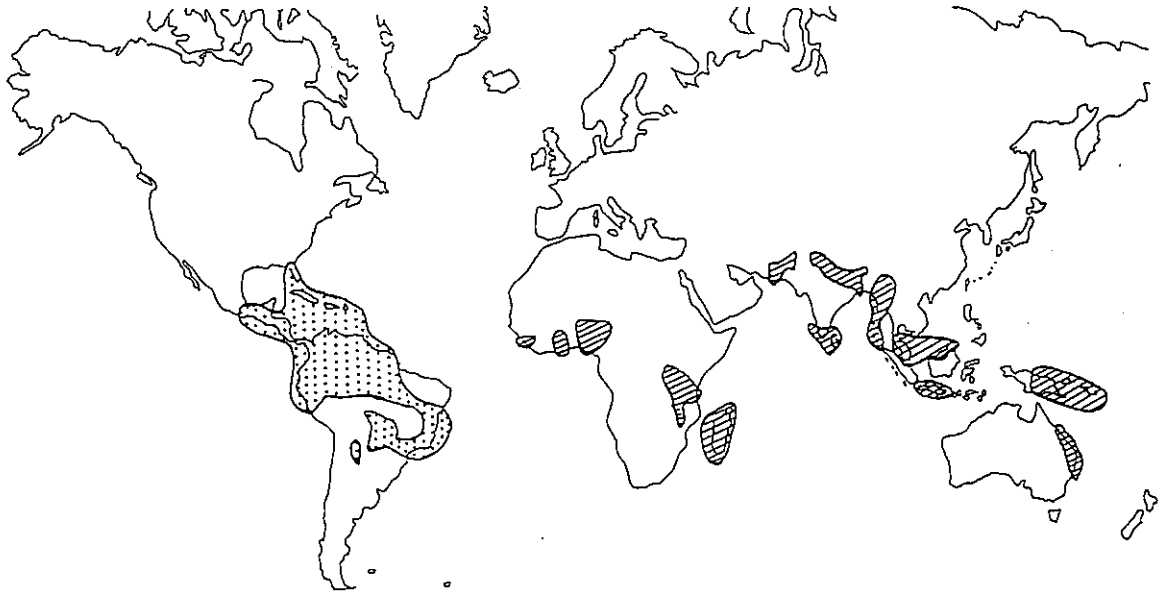

Fig. 1 Geographical distribution of *Hypsipyla grandella* (dotted) and *H. robusta* (oblique lines)

Table 1 Host tree species of *Hyposipyla grandella* and *H. robusta*

Tree species	*H. grandella*	*H. robusta*
Swietenia macrophylla	0	0
S. mahogani	0	0
S. humilis	0	
Cedrela odorata	0	☆
C. fissilis	0	
C. lilloi	0	
C. tubiflora	0	
C. procera	0	
Toona ciliata	☆	0
T. ciliata var. australis	☆	0
T. serrata	☆	0
Melia azadiracta	☆	0
Khaya anthotheca		0
K. grandifoliola		0
K. ivorensis		0
K. nyasica		0
K. senegalensis		0
Guarea trichilioids	0	
G. guara	0	
G. guianensis	0	
Lovoa trichilioides		0
Chloroxylon swietenia		0
Chukrasia tabularis		0
Entandrophgragma angolene		0
E. utile		0
Cedelinga catenaeformis★	0	0

Note 1. 0 : attacked, ☆ : not or less attacked
Note 2. ★ : Only cones are attacked.

areas and to develop measures of control of this pest.

Study site

The study site was set up in the Von Humbolt National Forest (9° S), approximately 80km west of Pucallupa which is located beside the river Ucayali, the upper stream of the Amazon. Afforestation areas for the project in the National Forest covered more than 700 ha, in which entomological studies were conducted mostly in the line-planting or opened areas. Average rainfall in the area exceeded 4,000mm/year, and the mean annual temperature was 25 °C.

Infestation levels and attack frequencies

The numbers of trees with current or previous *Hypsipyla* attacks were very large in the entire study area except for several plots. The less damaged trees were located in the natural regeneration area, one of the two under-planted *C. odorata* areas and in two line-planting areas with *S. macrophylla* (Table 2). However, tree growth was very poor due to shading by the surrounding vegetation. In an opened area with *C. odorata*, 98.7% of the trees were attacked once or more within 16 months after planting ; the number of attacks varied from 0 to 10, averaging 3.1 per tree (Yamazaki *et al*., 1992).

The life span of *H. grandella* reared in the laboratory was 38-44 days encluding the period of mating, indicating that there could be 7 generations per year. In contrast, phenological studies showed that sprouting occurred 3 to 5.5 times a year, mostly in the rainy season, on both *C. odorata* and *S. macrophylla*

Table 1 *H. grandella* infestation on 3 meliaceous species planted in varios ways.

Tree species	Area[1] code	No. of trees investigated	Year[2] of plantation	Percentage of trees[3] with current attacks	previous attacks
C. odorata	LP-1 (5m)	42	1982	12	100
	LP-2 (5m)	73	1984	33	41
	LP-3 (5m)	42	1984	38	50
	LP-4 (10m)	38	1984	34	—[5]
	LP-5 (10m)	78	1984	40	—
	LP-6 (30m)	35	1983	34	100
	LP-7 (30m)	169	1983	49	96
	Natural	40	1984[4]	18	18
	UP-1	19	1983	0	11
	UP-2	20	1984	95	100
	Opened area	161	1983	24	96
C. fissilis	LP-1 (5m)	19	1982	21	89
	Opened area-1	47	1984	96	98
	Opened area-2	20	1985	55	60
S. macropylla	LP-1 (5m)	36	1982	8	81
	LP-2 (5m)	73	1984	5	12
	LP-3 (5m)	50	1984	14	18
	LP-4 (10m)	47	1984	49	—
	LP-5 (10m)	36	1984	28	—

The investigation was conducted in September or October 1985.

1) LP : line planting area where trees were planted at a distance indicated by a numeral in parrentheses, Natural : natural regeneration area, UP : planting under the canopy of surrounding trees, Opened area : opened area less than 1 ha where trees were planted at 2-2.5 m spacing.
2) Trees were transplanted in January or February.
3) The current attack was the attack recognized currently by breaking of branches or shoots, or exudation of oleoresin, whereas the previons attack was the one recognized by the swelling-like knot associated with tissue regeneration for healing of the area previously attacked on the main stem .
4) Trees were 50-80 cm high at the time of investigation.
5) Not investigated.

(Yamazaki *et al.*, 1992). These data suggest that the trees are always exposed to *Hypsipyla* attacks whenever they have sprouted. In addition, even in the dry season, the adult moth which is attracted to the resin exuded from the stem previously attacked lays eggs nearby, resulting in the development of another generation.

Location of attack, on trees and developmental stages of insects

Investigations have been conducted during the season in which both insects and trees were most active (Table 3). Among a total of 2,620 *C. odorata* trees inspected nine times during the season, 362 (13.8 %) were attacked. Young larvae (1st to 2nd instars) were most frequently detected in the offshoots and their number decreased from the upper to the lower stem parts, whereas older larvae (3rd to 4th instars) congregated on the upper stem part. The 5th instar larvae and pupae were also most frequently found in the upper stem part but were distributed in other locations to some extent. These results indicate that hatched larvae feed on either newly developed shoots or fresh foliage, and then hollow out the stem mostly from the upper to the lower part as they develop. As there were very few younger larvae on trees with old or without foliage, the sprouting and development of young foliage are very important for the establishment of *H. grandella* population. The number of insects on an infested tree with foliage at various stages ranged from 1 to 4, averaging about 2.

Seasonal changes in frequency of attacks

Attack intensity started to increase in September (beginning of the rainy season), peaked in October, gradually decreased toward the end of the rainy season and further declined in the dry season from May to August (Fig. 2). The increase in the number of insect attacks was synchronous with rainfall, suggesting that the rapid development of new foliage triggered by rainfall at the beginning of the rainy season caused a rapid increase of the *Hypsipyla* population. However, it remains to be determined which factors

Table 3 Location of attacks by *H. grandella* and developmental stages in relation to the foliage conditions of *C. odorata* trees in the season from August 1988 to March 1989.

	No. of trees investigated	No. of trees attacked	No. insects														
			Offshoot			Upper part of stem			Middle port of detecles[1]			Lower part of stem			Total		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trees with new shoots[2]	282	36	34			10			8			2			54		
			26	8	0	1	9	0	5	2	1	0	0	2	32	19	3
Trees with fresh foliage[3]	681	181	111			199			78			0			388		
			76	32	3	3	155	41	4	65	9	0	0	0	83	252	53
Trees with old foliage[4]	1 343	141	20			177			59			10			266		
			8	9	3	3	105	69	7	15	37	1	1	8	19	130	117
Trees without foliage	314	4	0			6			2			0			8		
			0	0	0	0	2	4	0	0	2	0	0	0	0	2	6
Total	2 620	362	165			392			147			12			716		
			110	49	6	7	271	114	16	82	49	1	1	10	134	403	179

1) A: 1st to 2nd inster larvae, B: 3rd to 4th instar larvae, C: 5th instar larvae and pupae.
The main stem was divided into three parts and each portion was designated as the upper, the middle and the lower stem.
2) Tree with new soft shoots, approximately 20 cm long, and with or without fresh or old foliage.
3) Tree with fresh foliage and with or withour old foliage.
4) Tree with only old foliage.

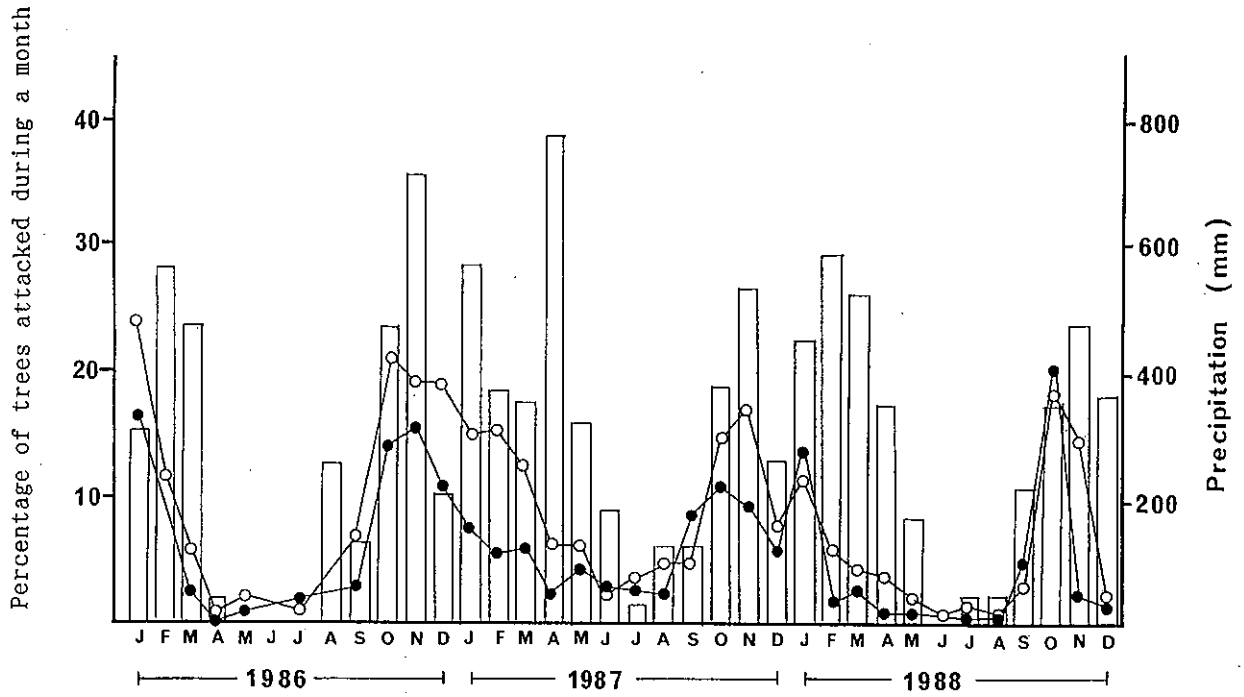

Fig. 2 Seasonnal changes in *H. grandella* infestation on *C. odorata* (○) and *S. macrophlla*(●).

prevented the *Hypsipyla* population from further increasing in spite of the additional supply of new shoots or fresh foliage throughout the rainy season and it could be assumed that natural enemies may have been involved in the control of the population (Yamazaki *et al*., 1990).

Host tree preference

As shown in Fig. 2, the annual mean in the percentage of attacked trees was slightly greater in *C. odorata* (8.47%) than in *S. macrophylla* (5.82%). In an opened rectangular area where 140 trees of each species were planted alternatively, *C. odorata* was more frequently attacked (23 trees or 16.4%) than *S. macrophylla* (1 tree or 0.7%) three months after planting. Moreover, in the host preference experiment carried out by placing 14 seedlings of *S. macrophylla* and 4 of *C. odorata* with young foliage on the same straight line, 3 out of 4 *C. odorata* trees were attacked whereas none of the *S. macrophylla* trees (1 tree or 0.7%) were attacked in a month. These results indicate that *H. grandella* preferred *C. odorata* to *S. macrophylla.*

Although *C. odorata* is more frequently attacked than *S. macrophylla* by *H. grandella* in Latin America, *C. odorata* introduced in other regions of the world is not or less attacked by *H. robusta* than native Meliaceae (Table 1, Grijpma 1970). On the other hand *Toona ciliata, T. ciliata var australis, T. serrata, Melia azadiracta* and some other Meliaceae which experience severe attacks of *H. robusta* in their native countries are resistant to the attack of *H. grandella* in Latin America. It was shown that these host selections depend on the native *Hypsipyla* moth and are based on the moth attraction to a specific odor of the host tree, particularly of young foliage (Grijpma and Gara, 1970).

However, *S. macrophylla* which is native to Latin America, is heavily attacked by *H. robusta* even in other regions of the world.

Moth behavior

The adult moth is nocturnal. The emergence of the moth begins at around 17 : 00, reaches a peak at 19 : 00–20 : 00 and ends a little after 20 : 00. Mating occurs between 20 : 00 and 23 : 00 and the eggs are laid between 21 : 00 and 24 : 00 after copulation. The female moth showed a characteristic flight behavior.

When *C. odorata* seedlings with new foliage were placed at various heights of the tower, they were most frequently attacked by *H. grandella* at a height of 0–2 m above the ground, and the higher the elevation, the fewer the attacks (Table 4). Seedlings damaged were concentrated at an elevation below 6m above the ground and the damage was limited above that level, suggesting that the female moth flies close to the ground level to search for host trees. The female moth can easily move to fresh foliage of young and low host trees due to attractive odor as well as her flying pattern.

Tree growth under various soil and topographical conditions

Tree growth was very poor in line planting, opened or natural regeneration areas (Table 5, and Fig. 3 and 4) due to the repeated insect attacks. However, even at such a low level of tree growth, some significant differences were found depending on the soil type in line planting areas where the light conditions were similar (Table 5). It appears that tree growth on acrisol (APO) was poorer than on gleysol (GPO) or cambisol (BVO), whereas, there was no significant difference in the tree growth depending on the topography in most areas except that the growth of trees either on a slope or top of a hill was very poor.

Table 4 Relationship between the fequency of attacks of H. grandella and hieght of C. odorata seedings.

Height of seedlings (m)	No. of seedlings	No. of attacks (%)		
		Aug-Oct, 1987	Nov-Dec, 1987	Mar-Aug, 1988
0 - 1	20	130(60.0)	28(1.9)	71(52.5)
2 - 3	20	49(19.2)	20(37.0)	21(15.6)
4 - 5	20	45(17.6)	5(9.3)	17(12.6)
6 - 7	20	11(4.3)	1(1.9)	13(9.6)
8 - 9	20	11(4.3)	0(0.0)	6(4.4)
10-11	20	9(3.5)	0(0.0)	7(5.2)
Total	120	255(100)	54(100)	135(100)

Chemical control

Three methods of chemical control were tested to reduce the damage as follows: soil treatment, stem or root injection and foliar application of insecticides. Soil treatment with 7 systemic insecticides (10 or 50 g each of Baycid, Orthene, Sancyde, Fradan, Advantage, Padan and Disiston) was not significantly effective in preventing the moth from attacking both *C. odorata* and *S. macrophylla* during the 120 day period after the treatment. Stem or root injection of Ortheni or Baycid also was not effective, whereas foliar application of insecticides, particularly pyrethroid, effectively decreased the damage of trees.

In a preliminary trial, the spray of Sumithion (fenitrothion, organo-phosphate) at 0.1% concentration onto *C. odorata* foliage was effective against larvae and prevented the oviposition for two weeks. However, the effectiveness lasted for less than one month after the spray. Sumithidine (a pyrethroid chemical) was more effective than Sumithion and the mean percentage of the trees attacked between the sprays was 4.8% for Sumithidine and 13.3% for Sumithion. Among the pyrethroid chemicals, such as Belmark (30% solution of fenvalerate), Sumithidine (20% fenvalerate) and Mikantop (30% fenpropathrin), Belmark remained effective a little longer than the others, although the percentages of attacked trees were low ranging between 1.2–2.2% for all the three treatments (spraying was carried out three times during the survey period from April to October).

Field trials for foliar spraying of Belmark were carried out in various areas. The growth rate of the trees treated with the chemicals was much higher (2 to 3 times) than that of the untreated trees (Fig. 3 and 4). When the trees (5m-d in Fig. 4), were treated with the chemicals three years after planting, the growth rates were the same as those of the trees treated from the beginning (5m-c).

Table 5 Tree growth under various soil and topographical conditions

	Period (days)	Growth increment						
		APO[1)]	GPO	BVO	BCO	Plane	Slope	Hill top
Cedrela odorata								
5m	966	1.17	1.03	1.55		1.13	1.37	1.13
5m	966	−0.15	1.14			1.38	−0.07	0.65
5m	966	0.61	1.60				0.95	0.83
10m	966	1.01	1.42			1.42	1.35	1.09
10m	966	−0.22	1.24			2.27	0.87	−0.30
10m	966	0.66	1.05					0.87
Open	695	3.22	3.18	2.79		3.18	3.07	3.21
Natural	860	0.30	0.69			0.68	0.42	2.61
Swietenia macrophylla								
5m	952	0.46	2.04	2.14	1.10	1.61	1.88	
5m	961	1.07	1.36			1.17	1.47	1.32
5-10m	961	1.58	1.55	1.43		1.51	1.62	
5-10m	973	0.54	1.65	1.76	0.95	1.60	1.27	1.62
5-10m	959	1.24	1.82	1.69	1.92	1.65	1.71	0.94
Open	703	1.39	2.42	1.50		2.43	1.43	
Natural	973				0.97		0.95	1.02

1) APO : plinthic acrisol, GPO : plinthic gleysol, BVO : vertic cambisol, BCO : chromic cambisol

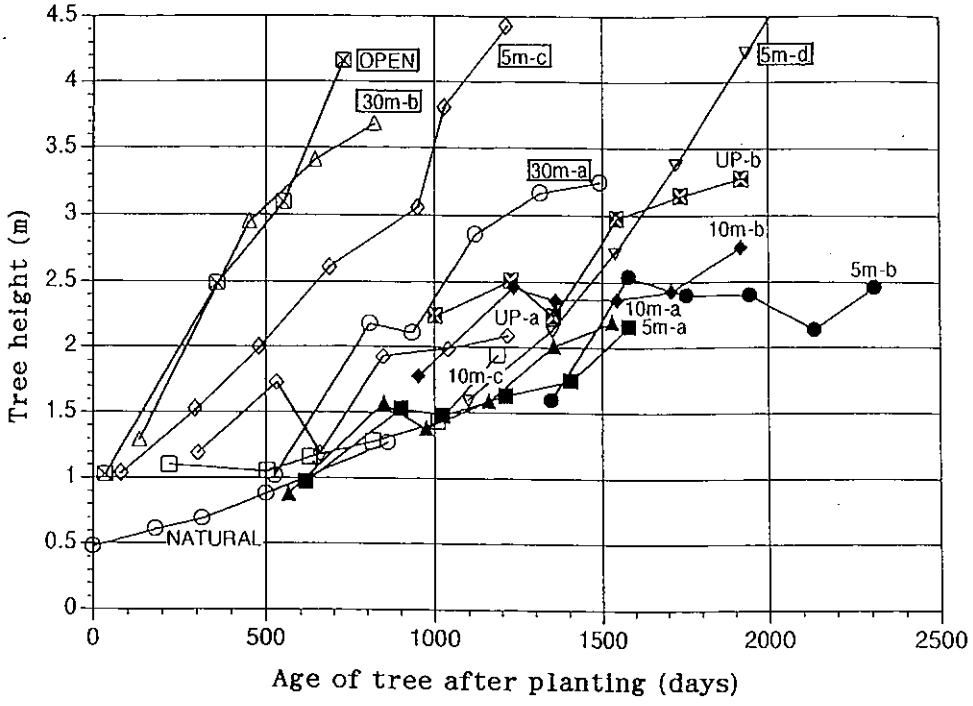

Fig. 3 Average height of *C.odorata* trees which survived after planting (□ : area sprayed with chemicals).

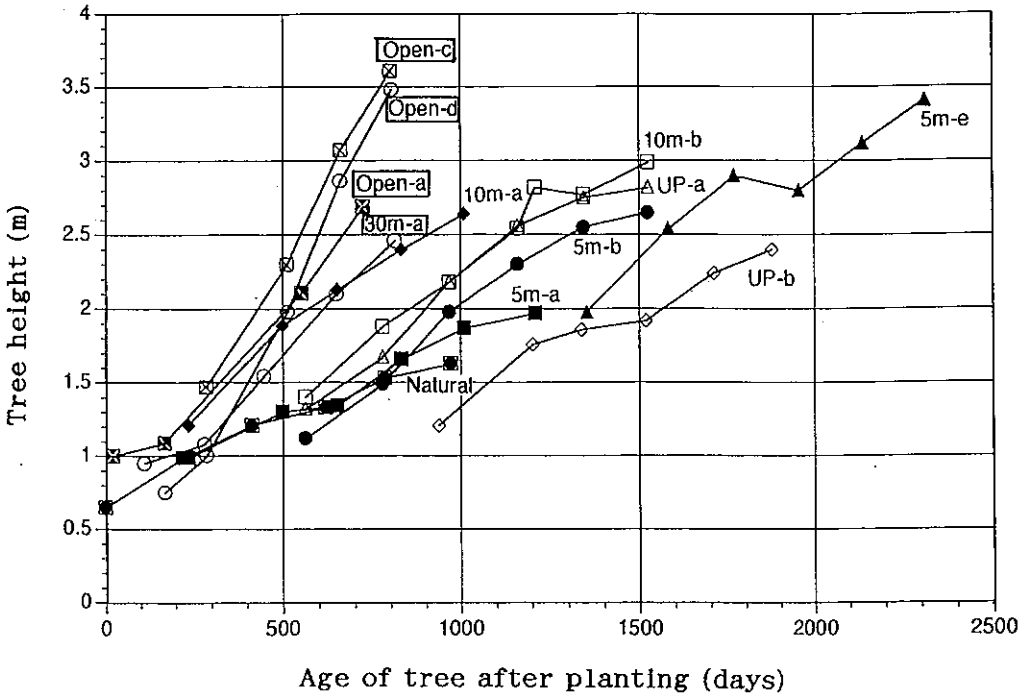

Fig. 4 Average height of *S.macrophylla* trees which survived after planting (□: our sprayis area sprayed with chemicals).

The main natural enemies identified in the study site included a parasitic nematode (Mermithidae),

Conclusion and recommendations for *Hypsipyla* management in a plantation

two parasitic wasps (Bracon sp. and Trichogramma sp.), and a fungus (*Beauveria* sp.). The larval parasitism of both the nematode and the wasps reached or sometimes exceeded a value of 10%. However, biological control with such agents has not been attempted yet. Therefore, the current measures for the management of *H. grandella* in the plantations of *C. odorata* and *S. macrophylla* are limited, and none of them except for the foliar spraying of insecticides has been successful on a large scale. Thus, planting trials with the combination of several measures will be necessary for the development of integrated pest management. Based on our experimental results and some control trials carried out on a small scale by other investigators, the measures currently recommended for the plantation of meliaceous trees are as follows:

1) To avoid an area with acrisol
2) To plant as far apart from remaining native forests, as possible
3) To keep neighboring grasses and bushes without cutting off as a female moth can not reach the host tree at a level below the surrounding grasses.
4) To provide enough space above the seedlings; both *C. odorata* and *S. macrophylla* require light.
5) To avoid planting in a group or along a line except when chemical treatment is available
6) To mix with insect repellent trees such as *Azadirachta indica*
7) To fence a plantation area with trees with dense branches and leaves 5-6m above the ground such as *Acacia mangium* to prevent the moth from flying into the plantation
8) To remove infested portions of host plants where larvae or pupae inhabit by hand 3-4 times a year; sprouting from the main stem occurs within several weeks
9) To prune and keep only one top shoot
10) To spray insecticides (fenvalerate) 3-5 times a year for *S. macrophylla* and more than 6 times for *C. odorata*

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