Field Tests on the Effectiveness of *Azadirachta* Companion Planting as a Shoot Borer Repellent to Protect Mahogany

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Abstract

Mahogany shoot borer, *Hypsipyla robusta*, is a serious pest of mahogany trees, whereas neem *Azadirachta indica* and sentang *A. excelsa* trees are sources of natural pesticides and insect repellents. Companion planting of these trees to protect mahogany plantations has been proposed as a control method, but so far no field experiment to test this possibility has been carried out. The present study, however, confirmed by three series of field experiments that mahogany (*Swietenia macrophylla*) trees alternately planted with neem (*A. indica*) or sentang (*A. excelsa*) were seriously attacked by the borer, indicating that companion planting of *Azadirachta* species does not protect mahogany from the borers attack.

Additional key words: Meliaceae, *Swietenia macrophylla, Azadirachta indica, Azadirachta excelsa*, neem, sentang, mixed planting, pest control

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Introduction

Mahogany shoot borers, *Hypsipyla robusta* Moore of the Old World and *H. grandella* (Zeller) of the New World (Lepidoptera: Pyralidae), are notorious pests of mahogany trees, *Swietenia* spp., and related *Khaya* spp., *Cedrela* spp., *Toona* spp., etc., of the family Meliaceae. The larvae bore into the shoot, and the infestation rate is almost always very high or total when the trees are at the sapling stage in young plantations. Once an attack by the borer on a top shoot occurs, it results in branching of the bole and so long and straight timbers cannot be harvested in the future. Despite many trials, no sure protection methods have been established (for reviews, see Newton et al.[13]; Mayhew & Newton[10]).

Silvicultural control, particularly mixed planting with other tree or crop species, has been attracting attention. It is empirically known that mahogany trees planted along enrichment lines in logged-over forests and those in mixed planting with other species suffer less attack by the borer than those in pure open plantings. The protection effects recognized in these non-monoculture plantations have been ascribed to the low planting density of mahoganies, overhead shading by the surrounding trees which limits shoot production by mahoganies, and lateral shading by the surrounding vegetation which limits access by the female adult moth[6), 8), 9), 10), 13)].

Some plant species have insect repellency, and employment of these species for companion planting to protect mahoganies has also been proposed, although the evidence is mostly anecdotal[10)]. In this respect, the neem tree *Azadirachta indica* A. Juss. (also Meliaceae), which is reknown as a source of natural pesticides, seems to be among the most hopeful. The species has several bioactive compounds of limonoids with highest concentration in seed kernels and lower levels in leaves and other tissues: these include azadirachtin, meliantriol and salannin which inhibit feeding or oviposition by insects; azadirachtin also disturbs insect metamorphosis[1), 4), 5), 11), 12), 15), 16)]. The less known sentang tree (Malay name), *A. excelsa* (Jack) Jacobs, is also promising as another source of azadirachtin and other compounds[7)]. Marrangin, another limonoid isolated from this tree, is similar to azadirachtin in structure and effects but is more active than the latter[2)].

Howard[3)] succeeded in protecting a small number of *S. mahagoni* by spraying an azadirachtin-based insecticide. However, whether companion planting of the *Azadirachta* species can provide adequate protection or not has never been tested in the field. In order to test this possibility, we carried out three series of field experiments.

Materials and methods

1) Study sites

The experiments were carried out in a concession area of the Sabah Foundation in the State Forest under the management of the Luasong Forestry Centre of the Sabah Foundation, approximately 70 km northwest of Tawau, Sabah State, Malaysia. Most of the concession area, totaling ca. 40,000 ha, has undergone commercial logging, but management of the forest is now strictly controlled by the state government. Clearance of the forest is forbidden unless otherwise licensed, and the Luasong Forestry Centre is conducting enrichment line planting with several rattan species inm the logged-over forest. An attempt was made to establish a mahogany *(Swietenia macrophylla)* plantation but was abandoned due to shoot borer attack. Rainfall is 2702 mm/annum and average temperature is 27.7℃ (based on records for 1990-98 at the Luasong Forestry Centre). Wet and dry periods may alternate, but no fixed seasonal pattern can be recognized (Fig. 1).

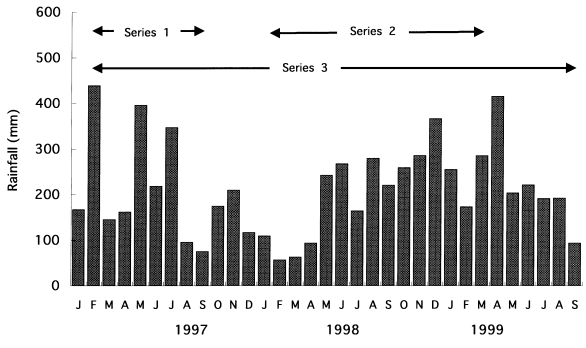

Fig. 1 Monthly precipitation in the Luasong Forestry Centre and periods of observation in experiment series 1,2 and 3.

2) Experimental planting material

Seeds of A. *indica* were provided by the Mata Ayer Research Station (Perlis Sate, Malaysia) of the Forest

Research Institute of Malaysia (FRIM). Bare-root *A. excelsa* imported from Thailand was purchased from a local dealer at Tawau. Seeds of *S. macrophylla* were collected at the Gum-Gum Experimental Garden of the Forest Research Centre (Sandakan). The planting stock was prepared in the nursery of the Pest and Disease Unit of the Luasong Forestry Centre.

3) Experiment Series 1: Open planting of similar size mahogany and Azadirachta sp.

Two open planting plots (0.1 ha each) with mixtures of *S. macrophylla* together with *A. indica,* and *S. macrophylla* together with *A. excelsa*, respectively, were established at the Tiagau experimental area in early February 1997 with the planting design shown in Fig. 2. The trees were planted at a 1.5 m distance from each other on the intersections of a 22 × 22 tree grid superimposed on a 31.5 m×31.5 m area. *S. macrophylla* and *Azadirachta* sp. trees were planted alternately on the intersections of an inner 20 × 20 grid, but only *Azadirachta* trees were planted along the edge. The distance between the two plots was ca. 200 m.

The incidence of attacks by *H. robusta* was recorded and tree heights were measured to the nearest 10 cm (depressed and broken trees inclusive) in the last week of every month from April 1997 to October 1997. Weeding was done as needed (approximately three month intervals).

4) Experiment Series 2: Open planting of smaller mahogany and taller Azadirachta sp.

To confirm whether *Azadirachta* trees bigger than mahogany trees can better protect the latter or not, we carried out a second series of experiments.

A plot for mixed planting of *S. macrophylla* and *A. indica* was re-created from that of series 1. The grown mahogany saplings were replaced with new smaller seedlings (30-40 cm in height), and dead and depressed *A. indica* trees were replaced with vigorous stock from the nursery taller than 1 m in height in early December, 1997.

Since the plot with a mixture of *S. macrophylla* and *A. excelsa* in series 1 had overly compacted soil in some parts and many of the trees did not grow well, we abandoned this plot and established a new plot about 40 m from the old one. We planted smaller *S. macrophylla* (30-40 cm) and taller *A. excelsa* (80-130 cm) in the same arrangement (Fig. 2) as in series 1 in late November, 1997. The distance between the two plots was again ca. 200 m.

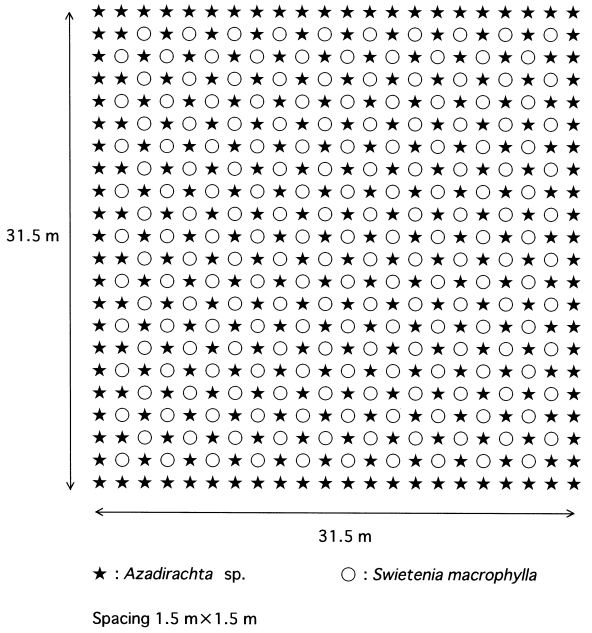

Fig. 2 Arrangement for open planting experiment series 1 and 2. Open circles indicate *Swietenia macrophlla* and stars either *Azadirachta indica* or *A. excelsa*.

Counts of shoot borer attack and measurement of tree height was done in the first week of every month from January 1998 to March 1999, and weeding practice was as in experiment series 1.

No control plot (pure planting of *S. macrophylla*) was established for the open planting experiments Series 1 and 2, due to shortage of available land.

5) Experiment Series 3: Line planting in a logged-over forest

Expecting the usual reduction of shoot borer attack in a line planting coupled with the repellent effect of the *Azadirachta* species, we established two more plots in the form of a mixed line planting of *S. macrophylla* together with *A. indica*, and *S. macrophylla* together with *A. excelsa* in a logged-over forest. In each plot, five lines of 3 m width, 25 m length and 10 m distance between each other (center line to center line) were cut. Seedlings of *S. macrophylla* and an *Azadirachta* sp. were alternately planted at intervals of 2 m within each line as shown in Fig. 3. The plot with a mixture of *S.*

macrophylla and *A. indica* was established on late January, 1997, and that with a mixture of *S. macrophylla* and *A. excelsa* late October, 1996. Establishment of the *S. macrophylla-A. indica* mixture plot was delayed three months, because we had to wait for *A. indica* seedlings to grow.

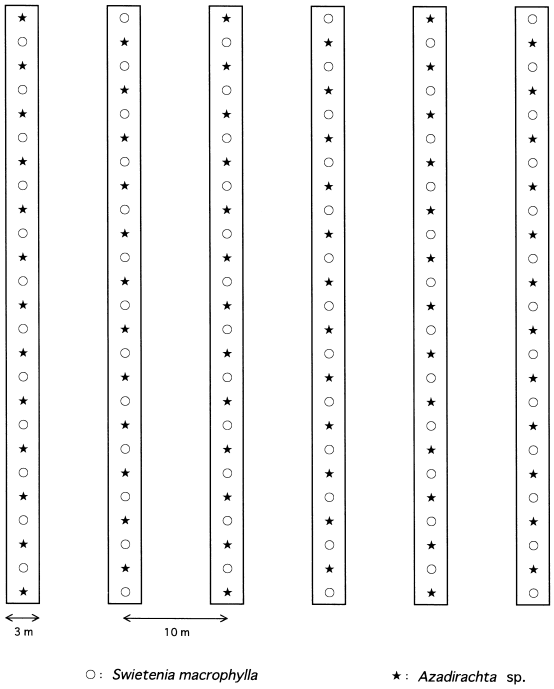

Fig. 3 Arrangement for line planting experiment series 3. Open circles indicate *Swietenia macrophylla* and stars either *Azadirachta indica* or *A. excelsa*.

The incidence of attack by shoot borers was counted and the height of the trees was measured in the last week of every other month from March 1997 to September 1999. Weeding was done at approximately four month intervals and hindering vines, shrubs and tree branches were cut back as necessary when measurements were taken.

We also established several other line planting plots for other purposes in the same compartment in a similar arrangement as the above-mentioned two mixture plots, but planted with different mahogany species. Among them one plot planted with *S. macrophylla* only, likewise in late October 1996, was available as a control for the present experiment. The distance between the two mixture plots was 1,000 m, between the *S. macrophylla-A. excelsa* mixture plot and the control plot 390 m, and between the *S. macrophylla-A. indica* mixture plot and the control plot 790 m.

Results

1) Experiment Series 1

Attack by H. robusta on *S. macrophylla* was first observed in June 1997 (four months after planting) in both plots, but the percentage of the attacked trees was very low (0.5%, or just one tree attacked) with *A. excelsa*, and it was not before August 1997 that the mahoganies with *A. excelsa* became frequently attacked. In contrast, the percentage of attack on mahoganies with *A. indica* was much higher: 68.0% for the mahoganies with *A. indica*, but only 23.4% with *A. excelsa* as of the last observation in October 1997 (Fig. 4). This difference was highly significant (χ^2-test, χ^2 =43.158, df=1, p<<0.001).

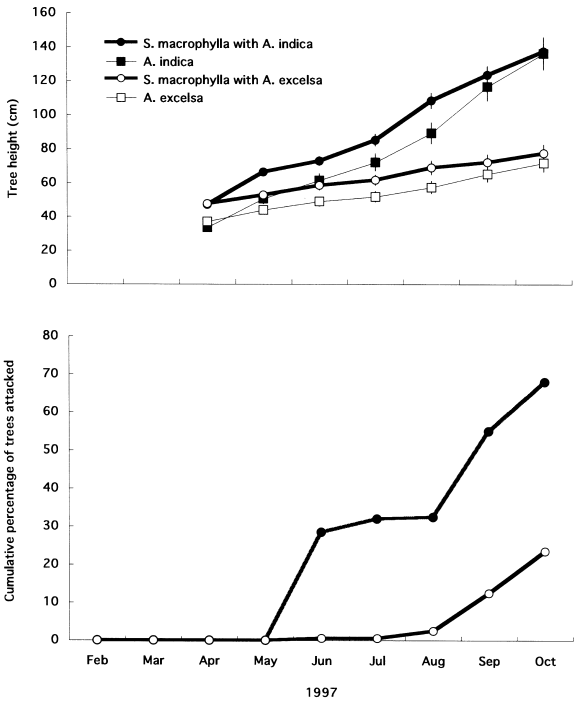

Fig. 4 Changes in average height (± 95% confidence limit) of the experimental trees (above) and cumulative percentage of *Swietenia macrophylla* trees attacked by *Hypsipyla robusta* (below) in mixed planting with *Azadirachta* indica and *A. excelsa* in two open planting plots in experiment series 1.

A. indica and *S. macrophylla* planted together in the same plot grew well, but *A. excelsa* and accompanied *S. macrophylla* did not, suggesting unfavorable conditions for the plants.

2) Experiment Series 2

The mahogany trees were frequently attacked in both

plots, whether with *A. indica* (plot A') or *A. excelsa* (plot B'). Attacked trees were first observed in July 1998 (ca. eight months after planting) in both companion planting (Fig. 5). The finally recorded percentage of attack (March 1999) was 45.8% for mahoganies with *A. indica* and 49.5% with *A. excelsa*, a difference that was not statistically significant(χ^2-test, χ^2 =0.315, df=1, n.s.).

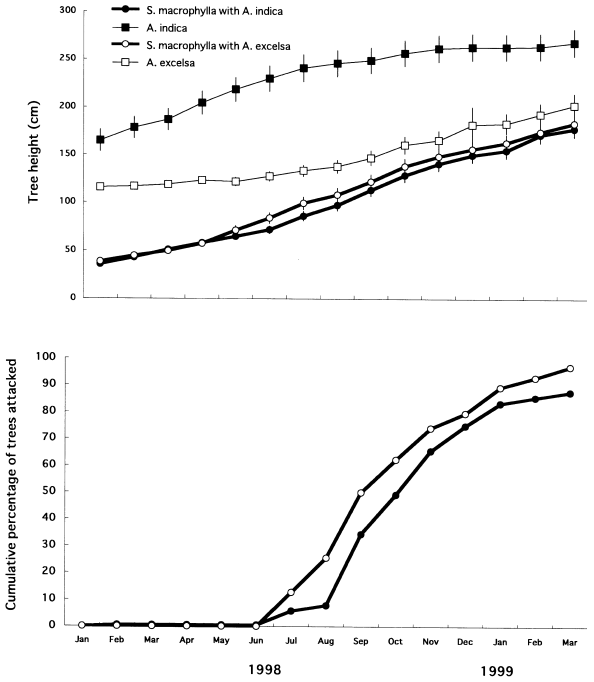

Fig. 5 Changes in average height (± 95% confidence limit) of the experimental trees (above) and cumulative percentage of *Swietenia macrophylla* trees attacked by *Hypsipyla robusta* (below) in mixed planting with *Azadirachta indica* and *A. excelsa* in two open planting plots in experiment series 2.

3) Experiment Series 3

The first attack was observed in November 1998 (22 months after planting) for mahoganies with *A. indica*, and in July 1998 (21 months) for those with *A. excelsa*. Thereafter the infestation rate steadily increased up to 67.2% for mahoganies with *A. indica* and 79.7% with *A. excelsa*, respectively, in September 1999. In the control plot, the first attack was observed in September 1998 and the infestation rate increased up to 61.6% in September 1999. Compared to the control plot, the incidence of attack in the two mixture plots was not low (Figs. 6), and no significant difference was detected among the three plots (χ^2-test, χ^2=2.378, df=2, n.s.).

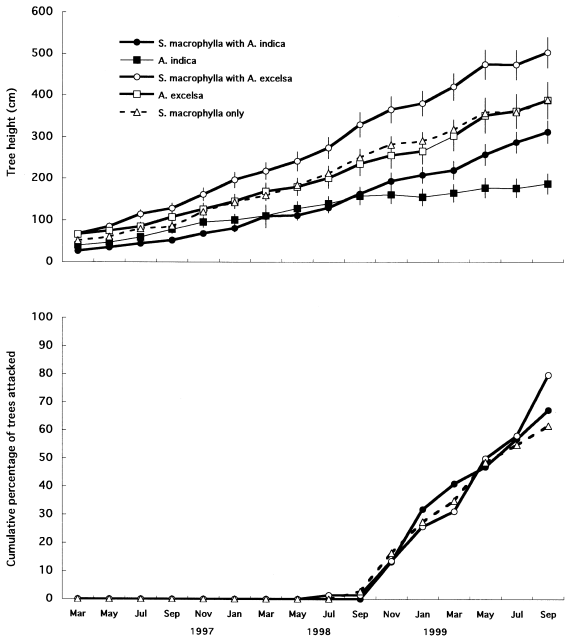

Fig. 6. Changes in average height (± 95% confidence limit) of the experimental trees (above) and cumulative percentage of *Swietenia macrophylla* trees attacked by *Hypsipyla robusta* (below) in mixed planting with *Azadirachta indica* and *A. excelsa* in two line planting plots in experiment series 3 and in a line planting plot with *S. macrophylla* only as a control.

Discussion

The patterns of attack varied among the experimental plots. The infestation level was higher in companion planting with *A. indica* than that with *A. excelsa* in experiment series 1, but the difference could not be due to stronger shoot borer repellency afforded by *A. excelsa*, because the infestation rates for companion plantings with *A. excelsa* were as high as those with *A. indica* in experiment series 2 and 3, respectively. The low infestation observed in the companion planting with *A. excelsa* in experiment series 1 can be attributed to poor shoot production. The soil in the plot for the *A. excelsa* companion planting was relatively compacted and both species of trees remained shorter in size (Fig. 4), indicating that the trees only infrequently produced shoots and/or produced only short shoots, conditions which are less attractive to ovipositing females of the shoot borer.

Delayed attack by shoot borers in experiment series 2 compared to experiment series 1 may be due to an extended dry spell during the first five months after establishment, rather than repellency of accompanied

taller *Azadirachta* trees, because the infestation rate steadily increased afterward with increased rainfall. In a study of *H. grandella* in Peru where pronounced dry and wet seasons periodically alternate, the shoot borer infestation rate increased with rainfall, which induces flashes of shoots[17]. The so-called "dry season" in Sabah is not so severe as in Peru, and a short drought in August and September 1997 (Fig. 1) did not depress the growth of mahoganies and attack by shoot borer in experiment series 1 (Fig. 4). However, five dry months, including the two driest months during this study, in the earlier part of experiment series 2 (Fig. 1) may have affected newly planted seedlings: the average height of *S. macrophylla* planted with *A. indica* in experiment series 1 was 72.9 cm in June 1997 (4 months after planting or when the first attack was observed; Fig. 4), whereas the average height of *S. macrophylla* in the same place in experiment series 2 reached a similar level (72.0 cm) in June 1998 (6 months after planting or one month before the first attack; Fig. 5).

Neither companion planting of *A. indica* nor *A. excelsa* showed effective reduction of attack by H. robusta on *S. macrophylla* trees. It may be that the planting interval of 1.5 m in the open planting experiments was still too distant to afford a repellent effect from *Azadirachta* trees. However, spacing closer than 1.5 m would be too dense and not practical for a timber producing plantation. Another idea to improve the mixing pattern would be to reduce *Swietenia* and increase *Azadirachta* trees. The repellent effects of *Azadirachta* species appeared so weak that only three or four trees accompanying a mahogany tree may not be enough to guard the latter. We are therefore pessimistic about the potential of *Azadirachta* as a companion planting to protect mahogany trees planted as a main crop. Mahoganies planted very sparsely among *Azadirachta* trees may be well protected either by the repellent effect or the physical obstacle effect of *Azadirachta*, but in this case mahogany would be a subsidiary crop in a *Azadirachta* plantation.

In experiment series 3, the first attack was observed in November 1998 (22 months after planting) in the mixture plot with *A. indica*, and in July 1998 (21 months) in the mixture plot with *A. excelsa*. Although the percentage of infestation increased to a high level thereafter, the considerable delay in the initial attack in these two line planting plots is intriguing. Lack of shoot borer attack for over 20 months after planting allowed mahogany trees to grow up to ca. 2 m in the mixture plot with *A. indica* and ca. 3 m in the mixture plot with *A. excelsa* with negligible levels of infestation. If attack by *H. robusta* could be further delayed several months by introducing additional protection in the line planting system, this would be an economically acceptable protection scenario.

Noraini & Jamilah[14] reported that Toona sinensis was an effective repellent plant for controlling pest attacks on neighboring plants, and suggested that T. sinensis may protect other mahogany trees from shoot borer attack if planted together. However, their experiments were based on small size seedlings set in a university campus for six weeks only. *Hypsipyla* shoot borers seldom attack small seedlings, and attack occurs several months after planting as in our study (Figs. 4-6). And supposedly shoot borers would not be abundant on a university campus. To test their hypothesis, a long term field study in a forestry area would be required. Mayhew & Newton[10] suggested that *Quassia amara* and Erythrina *poeppigigiana* may also be considered as candidates for companion plantings for borer repellency. It would be desirable to test these candidate trees in companion plantings in the field and report the outcome, even if negative. Negative results as obtained in this study are seldom reported, but here we would like to emphasize that negative results can also contribute to the development of protection methods.

Acknowledgement

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Azadirachta 属樹種とマホガニーの混合植栽による マホガニーマダラメイガの被害防除試験

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摘　要

マホガニーなど多くのセンダン科高級材生産樹種は、新梢穿孔性害虫のマホガニーマダラメイガ（*Hypsipyla robusta*）の被害が大きいため造林が阻まれている。その防除法の一つとしてマホガニー（*Swietenia macrophylla*）林分に昆虫忌避成分を含むインドセンダン属樹種(*Azadirachta indica*や*A. excelsa*)を混ぜて植える方法が期待されてきたが実証的研究はなかった。開放空間でのブロック状植栽2回および二次林内の列状植栽1回の3回の野外実験をそれぞれ*A. indica*と*A. excelsa*について行った結果、いずれの場合もマホガニーに被害が発生し、防除効果は認められなかった。

キーワード：センダン科，*Swietenia macrophylla, Azadirachta indica, Azadirachta excelsa,* ニーム、センタン、混合植栽、虫害防除

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