

Effects of Tree Shade on Attacks by the Red Cedar Shoot Borer, *Hypsipyla robusta* (Moore) (Lepidoptera: Pyralidae)

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ABSTRACT

The effects of shade on the attack by *Hypsipyla robusta* were investigated in red cedar seedlings (*Toona ciliata*) planted in the open (no shade) and under neem, *Azadirachta indica* A.Juss. (Meliaceae) shade. Seventy-two *T. ciliata* were planted in each plot. The trial was regularly monitored, assessing both the physical characteristics of the trees and damage by *H. robusta* at 12 and 24 months after planting. *T. ciliata* in the open plot was seriously attacked, with attacks at 12 and 24 months after planting of 93% (2 attacks/tree) and 100% (12 attacks/tree), respectively. *T. ciliata* planted under shade had no attacks at 12 months, but 43% of the seedlings were attacked (at least one attack/tree) at 24 months after planting. The general performance of *T. ciliata* trees in the open plot was very poor, while the trees under shade were in good form and taller than the trees in the open planted plot.

Key words: *Hypsipyla robusta*, shoot borer, *Toona ciliata*, *Azadirachta indica*, shade tree

INTRODUCTION

Red cedar (*Toona ciliata* M.J. Roem.) (Meliaceae: Swietenioideae) is an economic, fast-growing species which is widely distributed in the tropical forests of south and southeast Asia and north of Australia (Mayhew and Newton, 1998; Cunningham and Floyd, 2002). Red cedar is one of the potential species for timber production. Many countries have planted red cedar as an economically valuable timber. Its timber is primarily used for the construction of high-value furniture and interior fittings, as well as for light construction and building (RFD, no date). However, it has been virtually impossible to establish plantations of red cedar, because of

serious attacks by the red cedar shoot borer, *Hypsipyla robusta* (Moore).

Hypsipyla robusta (Moore) (Lepidoptera: Pyralidae) is the most important insect pest of trees in the Subfamily Swietenioideae of the family Meliaceae in tropical and subtropical regions (Beeson, 1919; Mayhew and Newton, 1998). *Hypsipyla robusta* is widely distributed throughout West and East Africa, Australia and the Pacific region, South and Southeast Asia (Beeson, 1941; Browne, 1968; Newton *et al.*, 1993). The damage caused by *H. robusta* results from attack by its larvae, which bore into and feed on the tip of the growing shoots. This leads to the death of the tender shoots and young leaves of red cedar seedlings and causes the generation of multiple

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shoots and numerous branches, resulting in poor form and stunted growth. *Hypsipyla robusta* produces several generations in a year and repeated attacks diminish the quantity and value of timber, particularly in the early establishment phase of plantations.

Several studies have been carried out using approaches to solve the problem in the establishment phase of plantations. Biological control, insecticidal control, silvicultural management, pheromone trapping and genetic resistance have been proposed to control *H. robusta* (Newton, 1993; Mayhew and Newton, 1998; Sakchoowong and Cunningham, 2002). However, none of these has proved successful commercially (Mayhew and Newton, 1998). Planting red cedar under shade trees may offer a possible method of silvicultural control to reduce shoot borer damage during the early establishment phase of plantations (Chey, 1996; Matsumoto *et al.*, 1997). Cunningham and Floyd (2002) reported that in under-planting red cedar trials in Australia, shaded trees a better performance than those trees planted in the open. Thus, this study investigated the effects of shade on attacks by *H. robusta*, by planting red cedar seedlings in the open (no shade) and under neem, *Azadirachta indica* A. Juss. (Meliaceae) shade. The experiment was undertaken at Phutoei Forest Plantation Station, Suphan Buri province. Data was collected 12 and 24 months after planting.

MATERIALS AND METHODS

Experimental plots

The experimental plots were established at Phutoei Forest Plantation Station located in Phutoei National Park, Dan Chang district, Suphan Buri province situated at latitude UTM 551000 E, 1653250 N and 250 m asl. The experimental plots were established on a slight sloped. Plots with 72 *T. ciliata* trees in each one were established in June 2003. The open plot (OP) was planted with trees at a spacing of 3×3 m and the plot with trees under shade (UP) was planted between the rows of a ten year-old neem plantation, with the spacing between *T. ciliata* of 4×4 m. *Toona ciliata* seedling was transferred to the experimental plots in June 2003 and the plots were generally maintained by Phutoei Forest Plantation Station for weed and fire control. Data on the number of attacks by *Hypsipyla robusta*, tree growth (height, diameter), number of branches and tree form were collected at 12 (June 2004) and 24 months (June 2005) after the establishment of the experimental plots (Table 1).

Data analysis

Data were analysed by t-test to detect statistically significant differences in the number of attacks, tree height, tree diameter (DBH), number of branches and tree form between treatments during 12 and 24 month periods after

Table 1 Description of measured data for open planting and under-shade planting of *Toona ciliata*.

Data collected	Method	Time
Number of attacks (from tip to trunk base)	Count of attacks	12 and 24 months after planting
Height of tree (cm)	Measurement of each tree (measuring pole)	12 and 24 months after planting
DBH (at 1.3 m from base of trunk) (cm)	Measurement of each tree (diameter tape)	12 and 24 months after planting
Tree form (scale from 1 = poorest to 5 = best)	Measurement by the same collector	24 months after planting

planting. The statistical analysis was performed with the Systat Software (1998).

RESULTS

Number of attacks between trees in the open plot (OP) and under shade plot (UP)

There was no attack on trees planted in UP 12 months after planting, while *H. robusta* attacked trees in OP with an average number of attacks of 2.18 ± 1.18 (Table 2). Thus, the data on the number of attacks, 12 months after planting from OP and UP could not be analysed. The number of attacks in OP had the greater increase 24 months after planting, with an average of

12.87 ± 4.6 attacks/tree (Table 2). While the attacks were found in UP 24 months after planting with an average of 0.78 ± 0.56 attacks/tree (Table 2), UP was attacked less than one time/tree. The average number of attacks 24 months after planting in OP was significantly higher than in UP ($T = 18.99$ $df = 85$, $P = 0.01$; Figure 1).

Percentage of attacks

Ninety three percent of trees in OP were infested after the 12-month period, with more than two attacks/tree. The attacks had accumulated after a 24-month period to 100% in OP. On the contrary, the trees in UP were not attacked 12 months after planting but 43% were attacked with less than one

Table 2 Mean (SD) parameters of number of attacks, number of branches, height, diameter (DBH), and tree form between treatments after 12 and 24 month periods from planting. OP = open planted plot, UP = under planted plot.

Tree age	Treatment	Number of attacks	Number of branches	Tree growth performance		
				Height (m)	Diameter (cm)	Form
12	OP	2.18 ± 1.18	2.27 ± 1.9	1.78 ± 1.2	2.45 ± 0.8	
	UP	No attack	0.15 ± 0.4	1.66 ± 0.6	1.25 ± 0.3	
24	OP	12.87 ± 4.6	10.04 ± 4.1	2.65 ± 0.8	5.06 ± 1.6	1.17 ± 0.3
	UP	0.78 ± 0.56	1.9 ± 2.6	3.28 ± 1.3	2.54 ± 1.2	4.5 ± 0.9

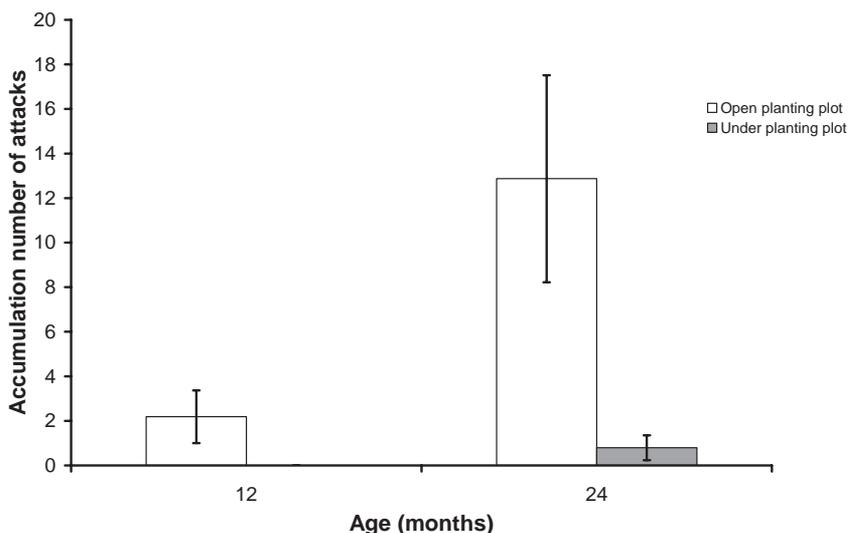


Figure 1 Number of attacks of *Hypsipyla robusta* at 12 and 24 months on *Toona ciliata* in open planted plot and under-shade planted plot.

attack/tree after the 24-month period. This indicated that the trees in OP were more often attacked by *H. robusta* than the trees in UP (Figure 2).

Tree growth characteristics

Tree height increment

After a 12-month period, the average tree height in OP was 1.78 ± 1.2 m and the average tree height in UP was 1.66 ± 0.6 m (Table 3). However, there was no significant difference between the open and under-shade planted plots 12 months after planting (T-test = -0.35, df = 132, $P > 0.05$).

After 24 months, the average tree height in OP was 2.65 ± 0.8 m, and the average tree height in UP was 3.28 ± 1.3 m. The trees in UP were also found to be significantly higher than the trees in OP (T-test = -2.063, df = 85, $P < 0.05$).

In the data analysis, the degrees of freedom for 24 months was less than that for 12 months after planting. This was caused by the mortality of trees from serious attack and also some trees died by chance in OP and UP after 24 months of study (Figure 3).

Tree diameter (DBH) increment

After 12 months, the average tree DBH in OP was 2.45 ± 0.8 cm, and in UP was 1.25 ± 0.3 cm (Table 2). The average DBH was significantly larger in OP than in UP, 12 (T-test = 9.31, df = 84, $P < 0.001$) and 24 months after planting (T-test = 7.81, df = 86, $P < 0.001$; Table 2). Again, the number of degrees of freedom was different between the data at 12 and 24 months because DBH was measured at a height of 1.30 m from the base of the trunk, trees that were shorter than 1.30 m and the dead trees were excluded (Figure 4).

Branch generating characteristics

The trees in OP were heavily attacked, causing the generation of multiple shoots. Numerous branches were produced, with an average number 12 and 24 months after planting of 2.27 ± 1.9 and 10.04 ± 4.1 branches/tree, respectively (Table 2; Figure 6). The trees in UP had good form with an average branch number at 12 and 24 months of 0.15 ± 0.4 and 1.9 ± 2.6 branches/tree, respectively. There was a significantly higher number of branches in OP than

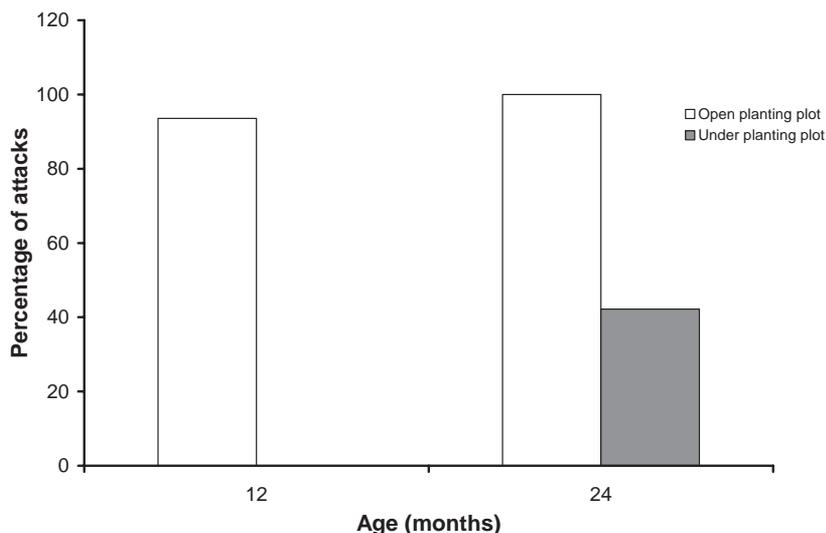


Figure 2 Progression of *Hysipyla robusta* attack after 12 and 24 months in *Toona ciliata* in open planting and under shade planting.

in UP, 12 months (t-test = 8.69, df = 132, $P < 0.001$), and 24 months (t-test = 10.66, df = 85, $P < 0.001$) after planting, respectively. When the trees were repeatedly attacked, the high rate of multiple branches generated increased linearly with the number of attacks as shown in Figure 5.

Tree form

There were no good-form trees recorded

in the OP at 24 months after planting and 95% of trees had very bad form (form = level 1 and 2) with an average form of 1.17 ± 0.3 . On the contrary, most *T. ciliata* in UP had good form (form = level 4 and 5) with an average form of 4.5 ± 0.9 (Table 2). Tree form was significantly different between treatments at $P < 0.05$ (t-test = 2.06, df = 85, $P < 0.05$) (Figures 6, 7 and 8).

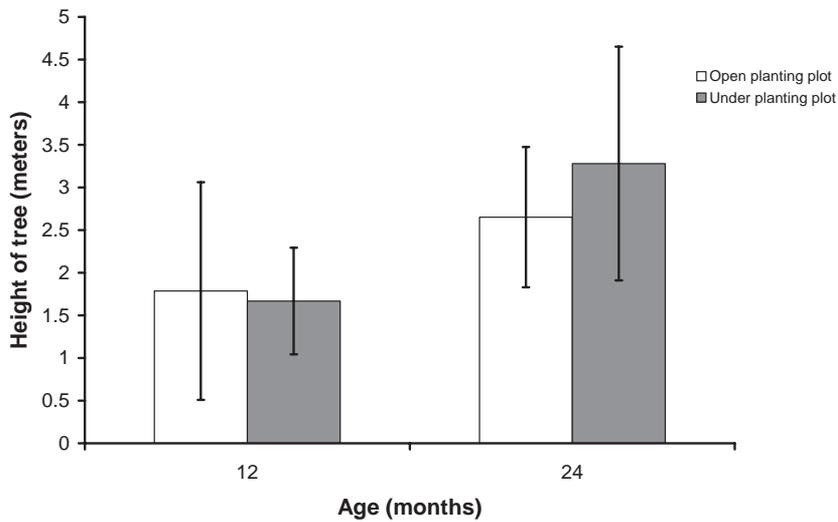


Figure 3 Height of *Toona ciliata* after 12 and 24 months in open planting and under shade planting.

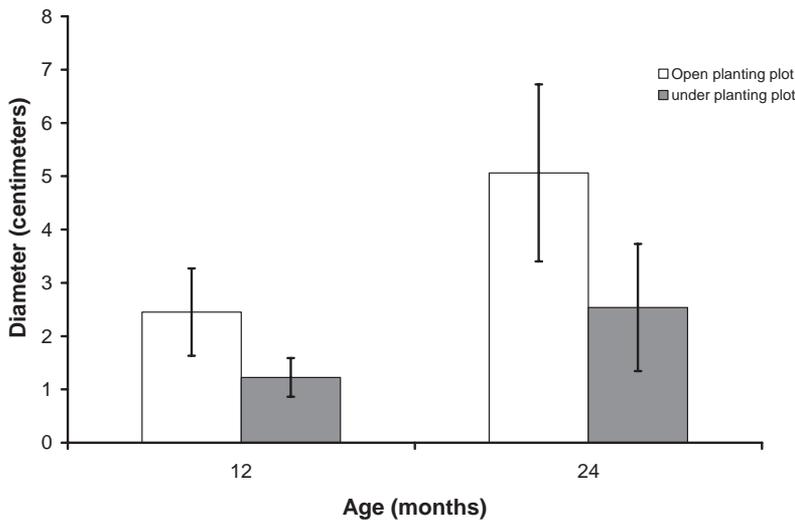


Figure 4 Diameter of *Toona ciliata* after 12 and 24 months in open planting and under shade planting.

DISCUSSION

***Hypsipyla robusta* infestation**

Infestation rates were high reaching almost 90% after 12 months in the open planting plot and the infestation reached 100% after 24 months (Figure 2). The high rates of infestation are a common phenomenon of *H. robusta* attack

in trees wherever the subfamily Swietenioideae is planted (Morgan and Suratmo, 1976). Beeson (1941) reported infestation rates of 100% found two years after planting. Chey (1996) reported that the infestation rate in mahogany, *Sweitenia macrophylla* was up to 90% two years after planting, and Sakchoowong and Cunninham (2002) found that *T. ciliata* from a genetic resource

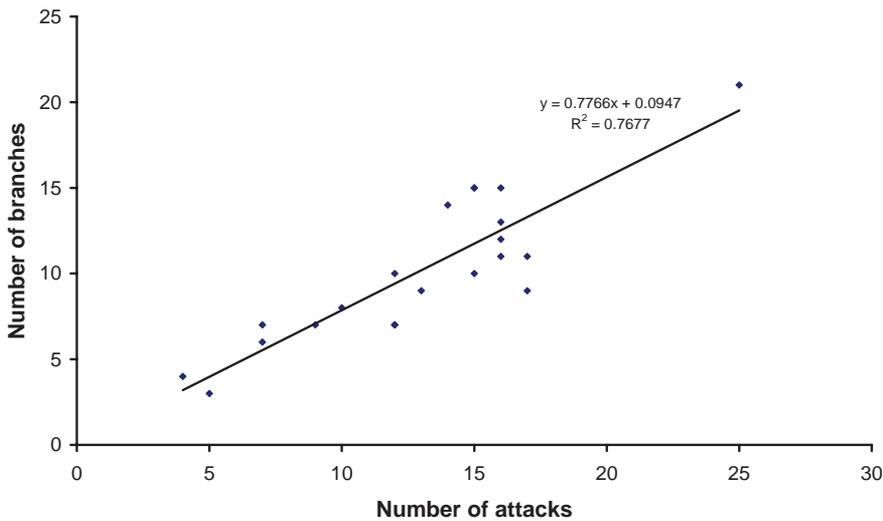


Figure 5 Relationship between number of attacks and number of branches after 24 months for *Toona ciliata* in open planting.

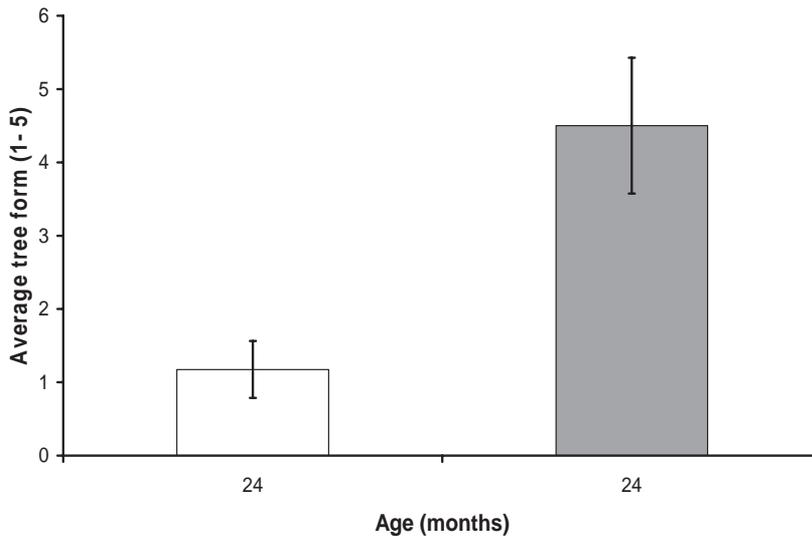


Figure 6 Tree form after 24 months for *Toona ciliata* in open planting (no filled color) and under shade planting (gray color).

trial in Prachuap Khiri Khan was infested starting six month after planting and after two years the infestation had reached 100%. The results in this study showed that planting *T. ciliata* under shade trees could prevent the attack of *H. robusta* in the first year and only 43% of trees were attacked in the second year with less than one attack/tree.

Similar reports on the effects of shade showed that the infestation rates were low in plantations which had been planted under shade trees (Chey, 1996; Matsumoto *et al.*, 1997; Perara, 1955; Weerawardene, 1996).

Why did tree shade produce the positive benefit of low levels of infestation? Cunningham



Figure 7 *T. ciliata* performance after 24 months in open planting plot.



Figure 8 *Toona ciliata* performance after 24 months in under shade planting plot. White arrows indicate *Toona ciliata*.

and Floyd (2002) reported an interesting supporting fact that the leaves of shade-grown trees attracted less laying of *H. robusta* eggs than leaves of open-grown trees. Another beneficial effect that prevented *T. ciliata* from infestation might have been the presence of an azadirachtin substance in *A. indica* leaves that could repel insects including *H. robusta* moths (DOAE, 2007). Thus, planting *T. ciliata* under shade trees could be one suitable management method to prevent and defer the attack of *H. robusta* in the newly established plantation by at least one year and lessen attacks for two years. This critical time is very important in the establishment of *T. ciliata* plantations.

Tree performance between OP and UP

All *T. ciliata* in OP had very poor form which resulted largely from the accumulated attacks by *H. robusta*. Among Subfamily Swietenioideae, *T. ciliata* is the most sensitive to attack by *H. robusta* (Mayhew and Newton, 1998; Cunningham and Floyd, 2002). In the second year of planting, tree form in OP was graded as level 1 or 2 and the height ranged from 1 – 2 m, while most trees in UP were of good form (graded as level 4 or 5) and tree height ranged from 2 – 5 m. The DBH of trees in OP was larger than for trees in UP. However, after the trees in UP reached the tip of the companion trees (shade trees), then DBH of *T. ciliata* in UP would increase as a result of the benefit from increased photosynthesis.

At an early stage after planting, the trees in OP showed slightly higher growth rates than those in UP. This indicated that the trees in OP had directly benefited from photosynthesis. However, tree height was not significantly different between treatments in the first year ($P > 0.05$). High infestation rates in OP resulted in multiple branching and stunted, tree height increment in later years, while the trees in UP had no infestation and fewer attacks in the second year, resulting in better height increment and performance compared to the trees in OP

($P < 0.05$).

Thus, planting *T. ciliata* in open-grown plantations would not be possible. This study suggested that the establishment of *T. ciliata* plantations should be under tree shade. The shade environment should be considered in terms of companion species, spacing, age of shade tree and tree height, i.e. tree shade should provide enough spacing for mixing *T. ciliata* between the rows of the shade tree species. Shade should be 50% and the height of the shade tree should be 6 to 10 m as it could be expected that the height of *T. ciliata* would reach this. However, further studies on shade are required to determine the precise mechanisms responsible, particularly the effect of shade on the production of plant compounds and chemical components in leaves under shade that do not attract the ovipositing of *H. robusta* females and larger experiments with more replications are also needed.

CONCLUSION

T. ciliata in open planting was infested 90% at 12 months and 100% at 24 months after planting. The severe infestation resulted in multiple branching, stunted growth and permanently poor form. But *T. ciliata* in shade planting had no infestation after 12 months and only 43% of trees were attacked with less than one attack /tree at 24 months after planting. Trees had good form and remained taller than those in the open-planted plot. Thus, planting *T. ciliata* under the influence of shade would prevent and defer the attack of *H. robusta* in recently established plantations which is a most critical time in *T. ciliata* plantations.

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