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Effects of Defoliation from an Outbreak of the Teak Skeletoniser, *Paliga damastesalis* Walker (Lepidoptera: Crambidae), on the Growth of Teak, *Tectona grandis* L.

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ABSTRACT

The effects of defoliation by the teak skeletoniser *Paliga damastesalis* Walker (Lepidoptera: Crambidae) on a six-month old stand of teak *Tectona grandis* L. was evaluated on the subsequent year-long growth in the field. Defoliation did not exceed 10%. It had a transient negative effect on post-defoliation height increment and new leaf production of up to two and three months of growth. However, defoliation severity significantly affected collar diameter increment up to the seventh month. A peak in the mean monthly growth increments for new leaf production occurred in April, followed by collar diameter increment in June and height in July. In addition, a peak in one of these three growth parameters also corresponded with a trough in the other or both of the other parameters; as such, the height increment peaked with a concomitant trough in collar diameter increment a month later. As for the remaining period of the dry season after July, new leaf production remained at a constant low level, while increments for both the height and collar diameter were found to decrease. Tree recovery appeared rapid with regard to these growth parameters, thus the impact of defoliation was generally and relatively negligible on the growth parameters measured.

Keywords: Collar diameter, defoliation, height increment, *Paliga damastesalis, Tectona grandis*

INTRODUCTION

Teak is an important exotic tree species in the Malaysian forest plantations (Ahmad Zuhaidi *et al*., 2002). However, it is often attacked by the teak skeletoniser, *Paliga damastesalis* Walker (Lepidoptera: Crambidae) (Intachat, 1997). This pest can cause severe defoliation on teak (Tho, 1981; Chey, 1999), with a complete denudation (Intachat, 1999). The effects of natural and simulated defoliation on various aspects of teak growth have been evaluated in several countries, such as India and Bangladesh, but the teak skeletoniser species *Paliga machoeralis* Walker is similar to *P. damastesalis* (Intachat, 1998). For instance, defoliation experienced during three consecutive outbreaks of *P. machoeralis*, within one growing season in India, was found to have caused losses in volume increment ranging from 8.3 – 65% (Tewari, 1992). Likewise, four consecutive annual artificial defoliations of 50% resulted in a 62% volume increment loss (Baksha and Crawley, 1998), while three consecutive artificial defoliations of 25% in one growing season reduced radial growth by 48% (Kirtibutr, 1983).

Information regarding defoliation effects on teak growth in Malaysia is limited to

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that reported by Hashim (2003), who found significant growth reduction in potted one year-old teak, especially when these seedlings were completely defoliated. The paucity of data on how defoliation affects teak growth precludes developing tools, such as economic threshold that aids in decision-making for control of this pest. The current arbitrary recommendations differ as to the defoliation levels that warrant the application of control measures, e.g. 30 to 50% (Tho, 1981), and exceeding 50% (Intachat, 1997). The baseline information regarding the impact of *P. damastesalis* defoliation on the growth performance of teak throughout this crop's rotation cycle is therefore needed to formulate economic injury levels for a range of tree ages. The present study evaluates the effects of natural defoliation by *P. damastesalis* on the growth of young teak trees in the field for a year.

MATERIALS AND METHODS

Experimental Site

The present study was conducted to determine the effects of defoliation by *P. damastesalis* on a six-month, even-aged stand of 629 teak trees with a mean height of 134.2 cm (range: 30-305 cm) planted on a level area of 0.52 ha of alluvial soil (Penambang series). This stand was maintained by the Mata Ayer Forest Research Station (FRIM), Perlis. The plot was surrounded by mature teaks. The outbreak occurred during the months of January and February 2000 at the onset of the dry season; with the mean annual precipitation ranging from 1800 to 1850 mm (Amir Husni *et al*., 1996). The rainfall data for the station for the year 2000 were also obtained from the Hydrology Unit (FRIM).

Assessment of defoliation

Defoliation assessment was initiated at the end of February 2000, i.e. approximately three weeks after the peak of the outbreak. A visual assessment of defoliation of every tree was also made, whereby every leaf was examined and the defoliation severity was estimated for each of the leaves. Meanwhile, the level of defoliation was categorised into four groups so as to estimate the overall loss in the leaf area; low (<25%), moderate (26-50%), high (51-75%), and very high (>76%).

The effects of varying degrees of defoliation on the subsequent growth of the trees were evaluated on a monthly basis to determine the growth parameters such as height, collar diameter increment, and the production of new leaves. Tree height was measured from the base of the tree to the tip of the apical shoot using a graduated bamboo measuring pole, while a stainless steel vernier caliper was used to measure collar diameter. The stem diameter at the base of the tree was considered as the collar diameter, instead of the diameter at breast height (dbh) as most of the trees were not tall enough for the dbh measurements. The production of new leaves was recorded by counting the number of leaves produced above the previous month's height measurement for the trees concerned. The study was carried out in a period of 10 months.

Statistical Analysis

The data analysis was carried out using the statistical software Minitab 14® (MINITAB, 2007) which included a Chi-square test and a correlation analysis (Neave and Worthington, 1992) with a reduced dataset of 436 trees instead of 629 trees. However, the final assessment excluded 21 dead and 170 damaged (bent and/or snapped trunk) trees mainly because the relationship between the initial defoliation severity and the death or damage of those trees which was recorded at the end of the study was ascertained as not significant ($\chi2 = 7.145$, $df = 3$, $p < 0.05$).

The final dataset was examined for the auto-correlations between the height, damage, and subsequent growth of trees since taller trees have been reported to experience more insect attacks that need to be controlled when analysing the effect of defoliation on height increment (Cunningham and Floyd, 2006). These were resolved using partial correlation to partition out the effects of interactions (Sokal and Rohlf, 1981). The partial correlation between defoliation level and monthly growth increment parameters, with initial tree size held constant, was calculated based on the procedure for the partial correlation given in Minitab14®. However, kurtosis in the first two monthly growth increment data could not be corrected using square-root-, log10- or inverse-transformations. Meanwhile, significant correlations among all the defoliation levels in the monthly growth increment parameters were measured over time (r > 0.95, $p < 0.001$ for all correlations). Therefore, the results were averaged across the defoliation levels to obtain the mean monthly growth increment for each of the parameters (*Fig. 1*). The residuals, obtained from the different regressing defoliation levels and the monthly growth increment on the initial tree size were correlated to give the corrected result.

The dataset was also examined for the trend of growth increment throughout the study period as averaged across defoliation levels. The defoliation levels were correlated to monthly growth increment for tree height, collar diameter, and new leaf production, while post-defoliation growth patterns were explored in relation to the monthly rainfall.

RESULTS

Insect defoliation never exceeded 10% on any tree at any time after the outbreak. Defoliation had a transient negative effect on height increment and new leaf production of up to 2-3 months; however, negative post-defoliation effects on collar diameter increment were observed up to the seventh month (Table 1). Over the entire study period, there was no significant association between height increment and defoliation severity (F = 0.62, d.f. = 1, 437, $p > 0.05$). The collar diameter increment, however, was significantly and negatively related to defoliation severity (F = 4.99, d.f. = 1, 437, $p < 0.05$) during that period.

The peak rainfall in April was matched by the peak in new leaf production, and this was followed by a peak in the increment of collar diameter in June. Meanwhile, the increment in height was found to reach its peak in July. A peak in one of these three growth parameters usually corresponded with a trough in the other or both of the other parameters. In March, however, when the new leaf production was at its highest, the increments in the height and collar diameter were found to be low. In April, the production of new leaves was minimal while the increment of collar diameter was at its peak. The height increment peaked with a concomitant trough in collar diameter increment a month later. As for the remaining period of the dry season after July, new leaf production remained low with decreases indicated for both height and collar diameter increments. However, the wet month of November saw a rise in height increment that was not shown in collar diameter increment.

The correlation analysis indicated that both defoliation severity and subsequent tree growth were potentially dependent on the size of trees. The defoliation level was negatively associated with the following month's growth increment, i.e. height increment (r = -0.17 and $p < 0.0010$), collar diameter increment (r = -0.09 and $p > 0.05$), and new leaf production (r = -0.07 and $p > 0.05$). The initial height of trees was positively associated with the height increment and new leaf production in the subsequent month, i.e. r = 0.323 and p < 0.001; r = 0.29 and p < 0.001, respectively, but it was found to be negatively associated with collar diameter increment, i.e. r = -0.10 and p < 0.05.

After the outbreak, other defoliators, such as *Hyblaea puera* Cramer and *Hypomeces squamosus* (Fabricius) (Coleoptera: Curculionidae), were occasionally detected during the monthly assessments. However, *P. damastesalis* was not found during the later part of the study period.

DISCUSSION

Since the ensuing insect defoliation never exceeded 10% on any tree at any time during the study, this incidence was considered as a one-time defoliation caused by *P. damastesalis*. Meanwhile, subsequent post-outbreak defoliation

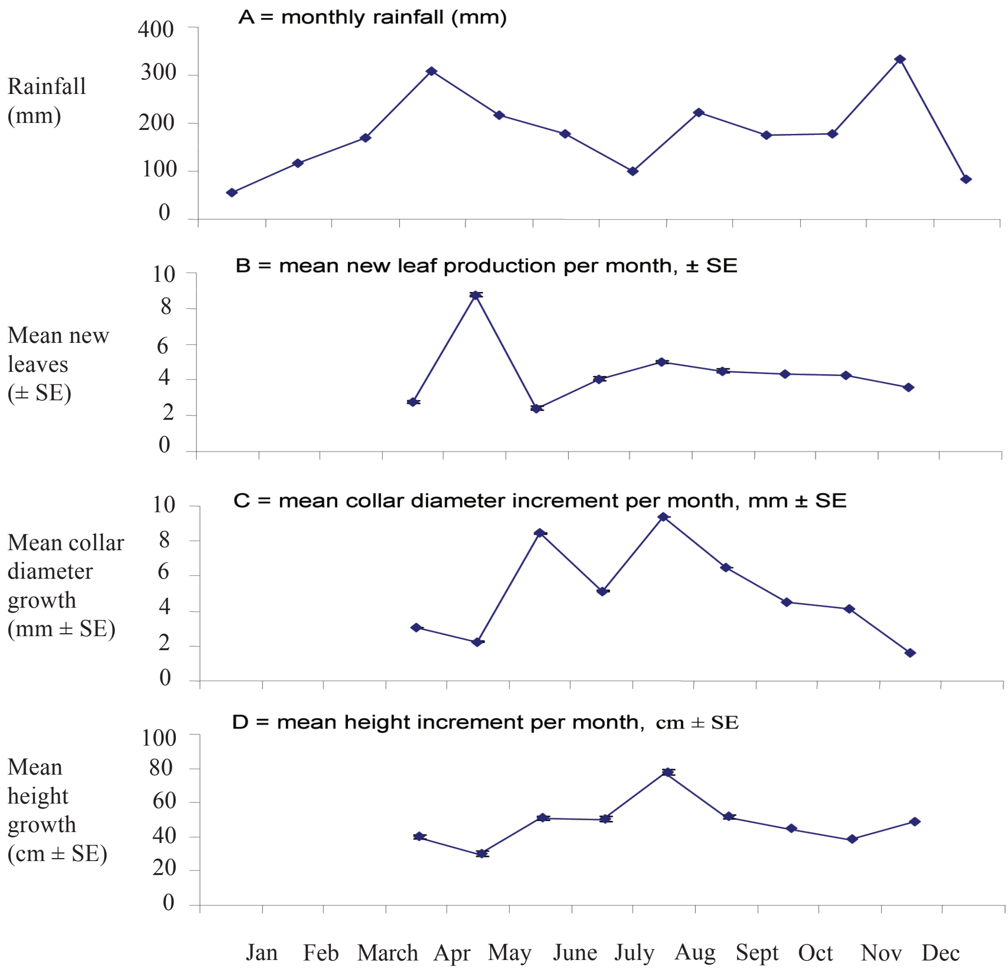

Fig. 1: Growth characteristics of six month-old teak (n = 436) in relation to rainfall after defoliation by P. damastesalis *at Mata Ayer, Perlis*

was shown to have a negligible effect on the measured growth parameters, i.e. height, collar diameter, and new leaf production. Therefore, the level of defoliation during the outbreak was the main factor influencing subsequent growth performance of the trees. No further loss was noted in the leaf area from the leaf fall due to defoliation which particularly affected the heavily skeletonised leaves (76-100% defoliation). Coley (1983) reported that leaves shed after defoliation increased the leaf area lost to insect herbivory in the tropical forests; thus conservative defoliation levels were recorded in the present study.

The occurrence of the outbreak during the dry month of January concurs with that noted by Intachat *et al.* (2000), whereby more severe attacks were reported during the dry spells in Sabah. However, Tho (1981) observed that defoliation was heaviest at the FRIM Mata Ayer field station from April to July, and attributed this to the leaf flush that followed the onset of the southwest monsoon in March. Chey (1999) suggested that pest was more abundant during wetter periods in Sabah, but found no significant correlation between the adult *P. damastesalis* population and rainfall in a year-long study. Although the general consensus

TABLE 1
Effect of *P. damastesalis* defoliation on monthly collar diameter and height increment, and new leaf production of six month-old teak

Month	Partial correlation between*			
	Df and Cd (Initial Cd held constant)	Df and Ht (Initial Ht held constant)	Df and New leaf production	
			Initial Ht held constant	Initial Cd held constant
1	-0.07 0.158	-0.29 0.00	-0.18 0.00	-0.16 0.001
2	-0.15 0.002	-0.19 0.00	-0.13 0.009	-0.11 0.026
3	0.004 0.933	0.02 0.741	-0.11 0.018	-0.12 0.014
4	0.02 0.027	0.07 0.161	0.06 0.233	0.05 0.337
5	-0.11 0.027	0.05 0.240	-0.04 0.455	-0.01 0.812
6	-0.01 0.867	0.04 0.363	-0.09 0.065	-0.07 0.130
7	-0.10 0.029	0.05 0.276	0.03 0.589	0.03 0.533
8	0.05 0.279	0.02 0.705	0.06 0.206	0.07 0.127
9	0.04 0.416	-0.02 0.714	0.02 0.661	0.04 0.468

Cells contain r (Pearson's) and p-value (italics). Significant correlation is given in bold-face.
* Df, defoliation increment; Cd=collar diameter increment; Ht=height increment. Partial correlation controlled for the initial height effect on both defoliation severity and subsequent growth (n = 436)

is that outbreaks of this pest occur seasonally, there remain conflicting observations as to the season in which outbreaks occur. Meanwhile, food availability and weather conditions, brought about by changes in the seasons, are probably two important factors contributing to the *P. damastesalis* outbreaks. Cold, dryness and/or rainfall are also thought to affect the *P. machoeralis* populations in India (Tewari, 1992). Furthermore, seasonal changes affecting weather could have indirectly affected insect populations, while the drought in the present study could have reduced nectar production from flowering weeds and depressed parasitoid populations.

A greater defoliation intensity observed with taller trees could have been due to being the first encountered by wind-borne female moths and/or perhaps as a result of preferential oviposition by the moths on taller trees. Gravid females may exhibit oviposition preferences for suitable host plants based on chemical cues (Hinton, 1981), while *P. damastesalis* females might have selectively oviposited on the healthier and taller trees. *Paliga damastesalis* is not a strong flier (Intachat, 1999), but if present in the plot prior to the outbreak, they could have conceivably reached the taller trees from their daytime ground vegetation refuges. Moths lay several eggs at a time on different leaves and the even defoliation pattern throughout the affected tree suggests that the moths are capable of flying to a height of at least three metres (Lim, personal communication).

The negative association between defoliation level and post-defoliation height increment and new leaf production for the initial two and three months, respectively, indicate short-term impacts of defoliation on these growth parameters. Tree recovery was fast with regard to these growth parameters. However, the variably depressed collar diameter increment, up to the seventh month of post-outbreak, suggests that girth expansion is affected more severely than height increment or new leaf production. Young trees such as those assessed in the present study could be badly affected by defoliation and/or other stress factors because they have less reserves upon which to draw from compared with older trees (Reekie, 1997). Food reserves stored in plant roots and stems that possibly support cambial growth could have been diverted for new leaf production after denudation. A severely defoliated plant would therefore need to restore such reserves before cambial growth could occur.

According to Hopkins (1999), factors influencing plant growth could be intrinsically mediated through genetic and hormonal reactions, as well as extrinsically through environmental factors such as light and moisture. This may be true in the case of the consecutive peaks in new leaf production, collar diameter and height increment. In addition, the plant is also capable of maximising growth, under variable environmental conditions over the study period, by adjusting within-plant allocation patterns (Bazzaz, 1997). In the present study, it is apparent that rainfall was the environmental factor that influenced tree growth across all the defoliation classes; however, within-plant shifts in allocation patterns could have probably resulted in the interactions among the growth parameters. During the transition period, i.e. from dry to wet season, a light flush of new leaves were produced to replace those shed due to defoliation and/or drought. The subsequent channelling of photoassimilate from maturing leaves to the vascular cambium probably explains the surge in collar diameter increment. Meanwhile, the girth expansion resulting from addition of structural tissue would then provide the mechanical support needed for further height increment or canopy expansion (Grace, 1997). The growth peak in June and the corresponding trough in height and collar diameter increments may reflect an alternating period of activity (photoassimilate uptake) in the apical meristem and vascular cambium. The findings gathered in the present study suggest that rainfall strongly influences the overall growth patterns of teak, the results which contradict with the ones reported by Chowdhury (1940). Fertilizing and irrigating trees following defoliation may boost their growth and aid in the recovery process. A complex interaction between the parameters measured seems to appear and this could be attributed to the inherent shifts in photoassimilate allocation.

CONCLUSIONS

Defoliation was found to have depressed the relative growth rates in relation to the level of defoliation experienced for the first two to three months after the outbreak. The reduction in growth was manifested by a reduced collar diameter increment, height increment, and new leaf production. An increase in one of these growth parameters corresponded with a decrease in either or both of the other parameters. Finally, the trees were observed to recover by the fourth month.

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