THE BIONOMICS OF THE TEAK SKELETONISER, *Paliga damastesalis* Walker (LEPIDOPTERA: CRAMBIDAE) AND ITS DEFOLIATION IMPACT ON YOUNG TEAK, *Tectona grandis* Linnaeus

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Agricultural Science

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Chairman: **Professor Yusof Ibrahim, Ph.D.**

Faculty: **Agriculture**

The distribution and feeding behaviour of a teak skeletoniser, *Paliga damastesalis* Walker, and the impact of its defoliation on the growth of young teak was investigated in a series of laboratory and field studies in Malaysia. A laboratory study on feeding behaviour showed that instar II to V larvae of *P. damastesalis* significantly preferred consuming leaf disks cut from young, expanding leaves of nodes 1 to 2 on two year-old trees, instead of leaf disks cut from mature, fully expanded leaves of nodes 3 to 5. Also, larvae that were confined to young leaves on pollarded two year-old trees a field study, fed and developed normally on those whole young leaves, indicating that secondary metabolites present in young whole leaves do not deter feeding or retard the growth of this insect significantly. Additionally, in that field study, larvae that were caged over mature leaves consumed a significantly larger leaf area in the fifth instar and had a significantly longer larval period than larvae caged over young leaves, while adult dry weights were not significantly different than that of larvae caged over young leaves.

This indicates that *P. damastesalis* may be able to compensate for lower nutritional leaf content by feeding longer and increasing consumption of the nutrient-poor leaves. The findings of the laboratory study on the preference of *P. damastesalis* for younger leaves were supported by a subsequent study on the within-tree distribution of the immature stages on 6 to 12 month-old teak planted along a highway. The larvae were strongly associated with the upper node leaves in the field, which are comparatively younger than the lower node leaves, suggesting that the larvae preferred and actively sought younger leaves to consume. However, oviposition behaviour may also have influenced larval distribution as the larvae may have completed their development on or not far from the eggs were laid. Since over 60% of the larvae were found on leaves of nodes two to four, sampling of leaves from these nodes was recommended for young teak grown in similar conditions, during non-outbreak periods. On another note, a skewed sex ratio with males consistently forming less than 3.5% of the samples was reported, and it was suggested that a pathogen causing male mortality in the embrogenic stage of *P. damastesalis* may be exerting an influence on those field populations of the insect. In a ten-month study on the impact of *P. damastesalis* defoliation on the growth of six month-old teak in a plantation environment, severity of defoliation showed a significant negative assocation with production of new leaves and relative growth rates for tree height and tree collar diameter, only for the first two months after the defoliation. For the remainder of the study there was no difference in the growth of the trees in relation to the level of defoliation they experienced.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

BIONOMIK ULAT PERANGGAS DAUN JATI, *Paliga damastesalis* Walker (LEPIDOPTERA: CRAMBIDAE) DAN IMPAK DEFOLIASI TERHADAP PERTUMBUHAN POKOK JATI MUDA, *Tectona grandis* Linnaeus

Oleh

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Taburan dan tabiat pemakanan ulat peranggas daun jati, *Paliga damastesalis* Walker (Lepidoptera: Crambidae), serta impak defoliasi ke atas pertumbuhan pokok jati muda telah disiasiat dalam kajian bersiri di makmal dan di lapangan di Malaysia. Kajian pemakanan di makmal menunjukkan bahawa larva *P. damastesalis* dari instar II-V memilih makan daun yang dikerat dari daun muda yang masih berkembang iaitu dari nod-nod 1 hingga 2 pada pokok berumur dua tahun, berbanding daun yang dikerat dari daun matang yang selesai perkembangannya, iaitu pada nod-nod 3 hingga 5. Juga, larva yang disangkarkan pada daun muda pokok yang dicantas yang berumur dua tahun di lapangan didapati makan dan berkembang secara biasa, menunjukkan bahawa metabolit sekunder dalam daun muda pokok lapangan tidak menghindar pemakanan atau merencatkan perkembangan serangga ini. Kajian tersebut juga mendapati bahawa larva yang disangkarkan pada daun matang telah memakan kawasan daun yang lebih luas semasa instar V dan tempoh peringkat larva lebih panjang berbanding larva yang

disangkarkan pada daun muda, tetapi berat kering dewasanya tidak berbeza. Maka *P. damastesalis* mungkin mengubahsuai pemakanannya dalam keadaan diet yang rendah tahap nutrien dengan meningkatkan kuantiti pemakanan dan melanjutkan tempoh pemakanannya. Pemilihan daun muda oleh *P. damastesalis* yang ditunjukkan di makmal telah disokong oleh kajian seterusnya di lapangan terhadap taburan peringkat muda serangga ini pada pokok yang berumur 6 hingga 12 bulan yang ditanam di sepanjang jalanraya. Larva ditemui pada daun di nod-nod bahagian atas pokok, yang lebih muda berbanding daun di nod-nod bahagian bawah. Ini mungkin disebabkan pergerakan larva ke daun-daun muda tersebut yang merupakan makanan pilihan mereka, tetapi mungkin juga disebabkan oleh tabiat peneluran betina dewasa di mana perkembangan larva disempurnakan pada atau berhampiran tapak peneluran. Oleh kerana lebih daripada 60% larva didapati pada daun di nod-nod 2 hingga 4, pengsampelan daun nod-nod tersebut disarankan untuk pokok jati muda yang ditanam dalam keadaan sepertimana dalam kajian tersebut, dan di luar masa wabak. Nisbah seks yang tidak seimbang telah ditemui di mana komposisi serangga jantan didapati kurang dari 3.5% daripada sampel-sampel. Sejenis kuman penyebab mortaliti pada peringkat embrio *P. damastesalis* mungkin menghadkan populasi serangga di kawasan tersebut. Dalam kajian impak defoliasi pada pokok jati berumur enam bulan di sebuah hutan ladang, tahap defoliasi dihubungkaitkan dengan pengurangan signifikan kadar pertumbuhan pokok jati berumur enam bulan hanya dalam dua bulan pertama selepas defoliasi tersebut, dan di sepanjang tempoh kajian selepas itu, tahap defoliasi yang dialami sesuatu pokok didapati tidak memberi kesan terhadap kadar pertumbuhan pokok tersebut.

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I certify that an Examination Committee met on 23rd July 2004 to conduct the final examination of Grace Tabitha Lim Wui Oi on her Master of Agricultural Science thesis entitled "The Bionomics of the Teak Skeletoniser, *Paliga damastesalis* Walker (Lepidoptera: Crambidae) and Its Defoliation Impact on Young Teak, *Tectona grandis* Linnaeus" in accordance with Universiti Putra Malaysia (Higher Degree) Act 1980 and Universiti Putra Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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CHAPTER 1

INTRODUCTION

Paliga damastesalis Walker is a serious pest of young teak (*Tectona grandis* Linnaeus) in Peninsular Malaysia (Intachat *et al*., 2000a) and the most important pest of teak in Sabah (Chey, 1999). It is one of the two economically important teak skeletoniser species in the world, the other being *Paliga machoeralis* Walker (syn: *Eutectona machoeralis, Hapalia machaeralis, Pyrausta machaeralis* (Roychoudhury & Joshi, 1997)), a closely related species of *P. damastesalis* that is a major pest of teak plantations in India (Patil & Thontadarya, 1983b; Mishra, 1992). It can cause up to a 100% defoliation of teak during outbreaks (Intachat, 1999), and is the chief cause of concern to the expanding plantation sector, which places much importance of teak as a valuable timber species (Baskaran *et al*., 1998). Teak is an exotic timber species in Malaysia, being indigenous to India, Myanmar, Thailand, Laos, Cambodia and Vietnam.

As teak is an important export and a forest plantation species in India, the teak skeletoniser species occuring there, i.e., *P. machoeralis*, has been researched extensively for many years. Numerous studies on its life history, behaviour, ecology, population dynamics and various control methods have been conducted (e.g., Misra, 1975; Patil & Thontadarya, 1983a; Patil & Thontadarya, 1987; Meshram, 1995; Meshram *et al*., 1997; Roychoudhury, 1999). While there is a great deal of information

available on *P. machoeralis*, only basic research has been conducted on *P. damastesalis*, following the recent emphasis on planting teak in Malaysia. Local research has yielded information on the life history of *P. damastesalis* (Intachat, 1999) and established that it is a different species from *P. machoeralis*, although similarities exist between the two (Intachat, 1998). Aqueous and methanol extracts of sentang leaf, bark and wood (*Azadirachta excelsa*) were found to suppress feeding of *P. damastesalis,* and some isolates of the microbial insecticide Bt (*Bacillus thuringiensis*, vars. kurstaki and aizawai) have been reported to have potential as environmentally-friendly insecticides for controlling this insect pest (Ng *et al*., 1998; Intachat *et al*., 2000c). Bt is a microbial insecticide used for control of a number of lepidopteran, dipteran and coleopteran pests by way of ingestion of the endotoxin it produces and subsequent paralysis of the insect gut (Schnepf *et al*., 1998) , while sentang is one of the two important congeneric species of neem (*Azadirachta indica*), of which leaf and seed extracts are used in commercial biopesticide formulations (Ng *et al*., 1999).

Paliga damastesalis has a life cycle of only 38 days and the female is capable of laying more than 100 eggs on average. The larvae feed on the succulent lamina and avoid the leaf veins and ribs, thus leaving the skeletonised leaf characteristic of defoliation caused by *P. damastesalis* (Intachat, 1999). Defoliation by the teak skeletoniser in Thailand, India, and Bangladesh has been shown to retard growth of the trees (Kirtibutr, 1983; Nair *et al*., 1996; and Baksha & Crawley, 1998a), and it is conjectured that defoliation on teak by *P. damastesalis* would similarly affect the trees (Intachat, 1997). However, not much is known concerning the actual impact of defoliation by *P. damastesalis* on

teak trees grown locally. Knowing the extent to which defoliation may affect the growth rate of the trees is important in deciding when to intervene with appropriate pest control methods in order to prevent serious losses in growth.

The study on the life history of *P. damastesalis* elucidated the duration and size of the five larval instars of the insect and included some observations on feeding behaviour (Intachat, 1999), but much more remains to be explored in the aspect of feeding behaviour, such as preference and factors influencing preference, if any. It was found that the fourth instar larvae of *P. machoeralis* that were fed young teak leaves gained more weight than those given mature leaves (Roychoudhury *et al*., 1995). This however, was a no-choice experiment, and while it observed that *P. machoeralis* preferred young leaves (Roychoudhury & Joshi, 1997), it was not quantified.

Outbreaks were observed to be seasonal (Tewari, 1992), and in Bangladesh it coincided with new flush of leaves (Baksha & Crawley, 1998b). Likewise, outbreaks of *P. damastesalis* in Malaysia are observed to be seasonal, but observations differ. Intachat *et al.* (2000b) noted attacks in Sabah were more severe during the dry spells, while Chey (1999) believed that the pest was more abundant during wetter periods. In Perlis, it was observed that defoliation coincided with the flushing of leaves following the onset of the southwest monsoon in March (Tho, 1981). Thus there is a need to investigate the possible seasonal abundance of this pest through regular monitoring of field populations. Currently, no sampling method has been recommended for estimating field populations of the teak skeletoniser, and for monitoring its population dynamics.

For the successful management of this pest, a thorough understanding of its behaviour and the factors which influence its distribution is essential. Towards this end, a series of studies was conducted with the following objectives:

First, to investigate the feeding behaviour of *P. damastesalis* under laboratory and field conditions. The laboratory study aimed to determine larval preference with regard to leaf age. To complement the laboratory study, the field study was designed to provide a comparison of leaf consumption and development between larvae fed excised leaves in the laboratory and larvae caged over leaves on trees in the field, in the context of secondary metabolite differences between the two. Additionally, the field study aimed to assess the influence of leaf age on leaf consumption and larval development.

Second, to determine the within-tree distribution of *P. damastesalis* on trees in the field. This study would provide the initial results that could be used as a basis for future development of a reliable sampling method for the pest. The findings of this study regarding the influence of larval food preference on the distribution of the larvae among the leaf nodes within each tree would complement results from the previous studies on feeding behaviour in the laboratory and field

Third, to measure the impact of defoliation by *P. damastesalis* on teak. The effects of defoliation on the growth increment of young teak trees were investigated and quantified in order to provide reasonable justification for further research on the insect.

CHAPTER 2

LITERATURE REVIEW

Distribution and Economic Importance of *P. damastesalis* Walker

The teak skeletoniser, *Paliga damastesalis* Walker, is found in Malaysia and Java. It has accompanied the introduction of teak (*Tectona grandis* Linnaeus) as an exotic species grown in forest plantations. In India, Myanmar, Thailand, Laos, Cambodia and Vietnam, where teak is indigenous (Appanah & Weinland, 1993), the teak skeletoniser is an important pest of teak. However, in India and Myanmar, the teak skeletoniser is *Paliga machoeralis* Walker (syn. *Eutectona machoeralis* Walker*, Hapalia machaeralis* Walker*, Pyrausta machaeralis* Walker (Roychoudhury & Joshi, 1997)), and while likewise identified in Thailand, more recent work has suggested the possibility that the teak skeletoniser species in Thailand is also *P. damastesalis* (Intachat, 1998). The two species are very similar and *Eutectona* is regarded as a junior synonym of *Paliga* (Shaffer *et al*., 1996). *E. machoeralis* is also referred to in literature as *Pyrausta machoeralis*, but it may be more accurate to refer to these as *Paliga machoeralis* (Intachat, 1998). In both *damastesalis* and *machoeralis*, the wings are yellow, but while *damastesalis* has red markings on the forewings, *machoeralis* has grey markings on both fore- and hind wings.

In India, Bangladesh and Thailand, *P. machoeralis* ranks together with another defoliating insect, *Hyblaea puera* Cramer, as a major pest of teak. As teak is an important export and a forest plantation species in these countries, teak skeletoniser species has been researched intensively for many years. In Malaysia *P. damastesalis* has also established itself as a serious pest, where outbreaks result in heavy teak defoliation (Tho, 1981; Chey, 1999). The trees are known to have been completely defoliated in some instances (Intachat, 1999). The recent emphasis on planting teak in Malaysia has stimulated research efforts on this teak skeletoniser species. This is timely in view of the government's efforts to intensify research in the priority areas of integrated pest management and sustainable forest management in plantation forests, particularly for lucrative timber species such as teak (Baskaran, 2000).

In Malaysia, although the trees rarely die even when completely defoliated, growth may be depressed, and the forking that often occurs young teak trees after severe defoliation results in future economic losses (Intachat, 1997). In Bangladesh, growth increment of teak trees has been shown to be greatly reduced by artificial defoliation. Yearly defoliation of 50% for four consecutive years on one year-old teak, caused serious losses in height, basal area and volume increment of 36, 55 and 62% respectively (Baksha & Crawley, 1998a). Reported losses in volume increment attributed to *P. machoeralis* defoliation varied from 8.3% to 65% following three periods of heavy defoliation in one growing season (reviewed by Tewari, 1992). In Thailand, there was a 48% reduction in radial growth after three consecutive artificial defoliations of 25% conducted in one growing season (Kirtibutr, 1983). Meanwhile, although the

defoliation levels by *P. machoeralis* in India did not significantly affect the growth of a four year-old teak stand in a five year study, complete defoliation by the teak leaf roller, *H. puera*, caused a 44% loss in potential increment (Nair *et al*., 1996).

It is likely that the impact of defoliation on locally grown teak would be equally adverse, and it would be useful to evaluate the impact of such loss of leaf area on growth. In addition to affecting growth, insect defoliation on plants directly and/or indirectly affects plant vigour, performance, competitiveness, recruitment, demography, and fitness. Furthermore, how the plant responds to a defoliation event depends on its type and age, species characteristics, available resources and the ecological context (Nowierski *et al*., 1999). In Malaysia, with the exception of an artificial defoliation experiment on seedlings in a potted trial (Hashim, 2003), the effect of defoliation on teak trees has not been studied. This has resulted in differing recommendations as to the levels of defoliation that warrant application of control measures, e.g. 30 to 50% (Tho, 1981), and exceeding 50% (Intachat, 1997). Much more information on the effect of *P. damastesalis* defoliation on teak is needed to evaluate its impact on growth performance, and for the formulation of economic injury levels and effective management strategies so that timely control measures can be applied.

The Host Plant: *Tectona grandis* Linnaeus (Verbenaceae)

Teak is a large tree, growing up to 45 m in height and attaining diameters of up to 100 cm. It is deciduous in nature and sheds it leaves during the dry season, which in

Malaysia is from the end of December to March, depending on soil moisture and varying with locality, while dormant buds emerge after the April to May rainy season (Hashim & Mohd Noor, 2002). Site requirements include deep, well-drained calcareous soil, with a neutral pH and annual rainfall of between 900 and 1600 mm (Behaghel, 1999). The root system of teak is superficial and depending on soil conditions, the feeding roots penetrate to a depth of 70 to 80 cm (Hashim & Mohd Noor, 2002). Additionally, a well-defined dry season is preferable, and in Peninsular Malaysia, teak thrives in the northern states that have a more pronounced dry spell, although growth performance further south has also been good. Under optimum conditions, one meter height increment a year can be achieved (Baskaran *et al*., 1998). A survey in Mata Ayer, Perlis, showed that the mean annual diameter growth of teak ranged from 1.1 to 1.5 cm for stands aged 8 to 31 years of age (Tang & Abd Kadir, 1979) and the MAI for volume has been estimated to be 5.0 to 6.0 m^3y^{-1} (Sandrasegaran, 1972).

The bark of teak is fibrous with shallow longitudinal cracks, and on older trees it peels off in long, thin narrow flakes. It is greyish brown in color and up to 15 mm thick, while inner bark is yellowish in color. Teak leaves are large, elliptic or obovate and entire, and are between 25 to 50 cm long and between 15 to 35 cm wide. Juvenile leaves are larger in size. The leaves are opposite on the stems. The upper sides of the leaves vary from rough to smooth and range from light to dark green in color, while the under sides are velvety and covered with tomentum (hairs) that range from grey, whitish to tawny in coloration. Young shoots vary from reddish green to brownish in color (Hashim & Mohd Noor, 2002).