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Emergence, Oviposition and Larval Behaviors in the Teak Beehole Borer (*Xyleutes ceramica* Wlk.) in Northern Thailand (Lepidoptera: Cossidae)

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Abstract

Adult emergence, oviposition and larval behaviors of the teak beehole borer (*Xyleutes ceramica*), a major pest moth of teak, were studied in the laboratory and the plantations in northern Thailand. Adult moths emerged mostly in March prior to the beginning of the rainy season. Females laid the greatest number of eggs on the first night after mating. Cumulative percentage of deposited eggs reached 79.2% on the 2nd night. The number of deposited eggs, which was estimated from weight, was 12,489 per female ranging from 3,666 to 21,094. A highly significant linear relationship existed between the numbers of eggs and the weight of an egg batch. Mated female longevity was 7 days on average. Eggs were laid in a mass mostly beneath the scales of bark of teak trunks in the field. An ovipositing female staying on a young teak tree in nature was also observed dropping her eggs to the ground. This is the first record of the finding of eggs and the oviposition behaviors of the moth in the field. Experimentally released larvae showed positive geotaxis both on the cut logs and on the living teak trunks. On the living teak trunks, larvae frequently changed their boring sites before June, but in early July, 37.5% of surviving larvae remained in the same boring sites as in the previous month and 78.6% in early August. All larvae settled down in particular boring sites in September. Control tactics for the teak beehole borer were also discussed in view of the oviposition behaviors.

Discipline: Forestry and forest products

Additional key words: adult survivorship, larval dispersion, oviposition site, *Tectona grandis*

Introduction

Teak (*Tectona grandis* Linn. f., Verbenaceae) is one of the most valuable timber species in tropical Asia for its durability and high quality of wood[15,16]. Thus it has been planted widely in Asian and African countries beyond its natural distribution[10,16]. In Thailand, man-made teak forests have increased to 170,000 ha since the first plantation in 1906, expanding mainly in the northern part of the country[16]. As trees grow, however, the plantations of teak have been faced with the deterioration of wood quality due to the infestation by the teak beehole borer (*Xyleutes ceramica*, hereafter called TBB), the most serious pest of teak[4,5,9]. The larva of TBB badly infests the living tree burrowing a long tunnel called "beehole" inside a trunk[1–3].

The bionomics of TBB has been extensively studied in Myanmar[1,2], where the adult emergence, larval and oviposition behaviors have been described. The seasonal abundance of adults throughout a flying season has been analyzed for the first time in Thailand[6] and a strong tendency for aggregation of emergence within stands has been also reported[13]. More data, however, should be documented to clarify the pattern and variation of adult emergence. On the other hand, very little has been numerically known about egg-laying behavior, larval dispersion and boring behavior in relation to season progression.

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Especially, the oviposition sites of TBB in the field have remained unknown for a long time, despite extensive field investigations[1,2].

We studied the bionomics and the population dynamics of TBB, especially focusing on the clarification of behaviors and life table construction, in northern Thailand from 1990 to 1993 under the Research and Training in Re-Afforestation Project cooperated by the Royal Forest Department of Thailand and the Japan International Cooperation Agency of Japan (JICA). In the present paper we report the results on adult emergence, oviposition and larval behaviors.

Materials and methods

1. Monitoring adult emergence

Emergence of TBB adults was monitored in the Maegar Seed Orchard Phayao (99°55′ E, 19°10′ N), Lampang Province from 1991 to 1993. In every December, teak trees were randomly examined to locate new beeholes, which were ejecting fresh frasses or had hole openings sealed with silk wads. Then wire netting traps were set up to cover the openings of beeholes. The number of traps set up was about 1,000 every year. Emerged adult moths were daily collected, sexed and counted to record the number of females and males from late February to March in 1991 and in March in 1992 and 1993. The difference from 0.5 in the sex ratio was statistically tested with *G*-test[14].

2. Oviposition in laboratory

The studies on oviposition behaviors were conducted in a laboratory in the Northern Pest Control Center, Ngao (99°58′ E, 18°45′ N), Phayao Province in March 1990 and 1991. Since females of TBB lay a large number of minute eggs in a mass, it is not practical to count the number of all eggs. We, therefore, estimated the relationship between the number of eggs and the weight of an egg mass. From each of ten different egg masses laid by different females, an unknown batch of eggs was isolated, weighed by a balance and its number was counted under a microscope. Their relationship was analyzed with simple linear regression[14].

Oviposition schedule was studied for 15 females. Unmated females and males, which were caught by the emergence traps in the Maegar Seed Orchard, were kept in a screen cage (40 cm × 40 cm × 40 cm) for mating. Only the females mated on the first night after emergence were used for the study. Under natural photoperiod, the mated females were singly kept in a paper bag (20 cm × 30 cm) containing tissue papers, on which females often laid egg masses. No food was supplied to them because adult moths have a vestigial mouth, but wet tissue paper was provided in the bag to avoid excessive desiccation. The egg masses were collected daily until the female died and they were weighed the next day after oviposition to estimate the number of eggs, using the regression equation mentioned above. Mesonotum length was measured for each female at death. The Kendall rank correlation[14] was employed to assess the relationship between the total number of deposited eggs and mesonotum length or longevity, and between the mesonotum length and longevity, since our data including discrete variables did not conform to a bivariate normal distribution.

3. Search for egg masses and ovipositing females in the field

The field search on oviposition sites of TBB was conducted at a 16 year-old stand in the Mae Li Plantation of Forestry Industry Organization, Li (98°57′ E, 17°48′ N), Lamphun Province, on 18 March 1992. This well-grown stand with a site index of 30 based on diameter at breast height (DBH) had been heavily attacked by TBB. To find the location of oviposition sites, one hundred trees were randomly sampled and carefully examined from the ground around the tree base to the crown which included pealing off scales of bark to locate eggs. The height and DBH of trees bearing egg masses and the height of the egg mass from the ground were recorded. We searched for ovipositing females in nature at night from19:00 to 23:00 in the Maegar Seed Orchard during March 1992.

4. Experimental release of larvae

In order to investigate the behaviors of hatched larvae, six egg masses at hatching, which had been weighed in advance to estimate the number of eggs, were placed at 150 cm above the ground on each of six fresh cut logs (2 m in length) of teak that stood on the ground in a wooden hut in the Mae Gar Seed Orchard on 29 March 1990. The number of larvae released was 1,744 on average. The entry holes bored by the hatching larvae were counted every day after the hatching of larvae. To avoid predation by ants, lizards, etc., a sticky paper (30 cm × 30 cm) was placed at both the bottom and the top of the cut log. The hatching larvae caught by these sticky papers were also counted.

The behaviors of young to mature larvae were also studied on living teak trees in a 10-year-old stand at the Teak Improvement Center, Ngao. Egg masses at hatching were placed on trunks of 8 trees at the height of 3 m from the ground in April 1992. The mean diameter at breast height of these trees was 17.4 cm, corresponding to very good growth of site index 30; this index indicates the forest site quality of a stand, generally based on tree height or diameter at a given age. The number of larvae released per tree was 2,398. Prior to the release, the tree trunks were carefully examined to remove egg masses if deposited. The survivors indicated by the holes ejecting fresh frasses were counted every month until November and these holes were marked with a felt-tip pen and measured for their height on the trunk from the ground. When counting the number of holes, the current frasses were once brushed off and then the holes that ejected new frasses were counted one or two days after brushing. This is because the holes with frasses do not always contain living larva as young larvae frequently change boring sites.

Results

1. Adult emergence

The numbers of males and females caught by emergence traps were 210 and 372, respectively, in 1991, 126 and 124 in 1992, while only 19 and 49 in 1993. Female ratios were 0.64 in 1991 and 0.72 in 1993, significantly female-biased from 0.5 (G-test, $G_{adj} = 45.65$, $p < 0.005$ for 1991; $G_{adj} = 15.39$, $p < 0.005$ for 1993), while it was 0.496 in 1992, not significantly biased ($G_{adj} = 0.02$, $p > 0.5$). Daily and cumulative emergence of TBB in 3 yrs is presented in Fig. 1. In 1991, the adults began to emerge from February 27 for both sexes, and steadily increased in number toward the middle of March (Fig. 1, A). The maximum daily emergence occurred on March 12, 2 weeks after the first emergence for both sexes, and then the emergence declined toward the end of the month. The cumulative curves of emergence show that both sexes had the same emergence pattern this year. Date of 50% emergence was March 9 for both sexes.

In 1992, although the date of the first emergence was not detected due to later start of monitoring than in 1991, the emergence pattern was similar to that in 1991 (Fig. 1, B). That is, the emergence peaked in the middle of March, and then declined toward the end of the month. On the other hand, such a pattern of emergence as in 1991 and 1992 was not observed in 1993. Emergence commenced on March 6 for both sexes (Fig. 1, C), later than in 1991 and 1992. Daily number of emergence of both sexes fluctuated irregularly. Especially, no male emergence was observed on 12 days during the period of monitoring, although females emerged almost every day. Date of 50% male emergence was May 10, while the cumulative female emergence was 41.1% on that date.

2. Oviposition schedule

A highly significant linear relationship was obtained between the numbers of eggs and the weight of an egg batch (Fig.2). This equation was used for the estimation of the number of eggs in the following studies.

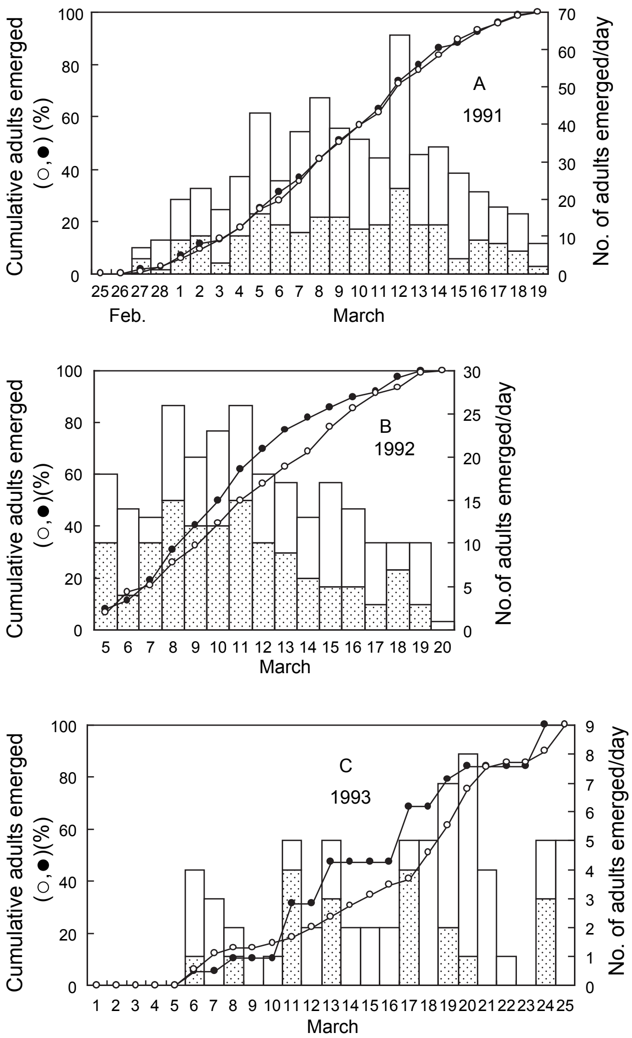

Fig. 1. Daily (columns) and cumulative (lines) emergence of *X. ceramica*

□, ○: Female, ⬚, ●: Male.

Closed circle and hatched bar indicate male; open circle and white bar indicate female.

The number of eggs laid per female and longevity of adult females are summarized in Table 1. The pre-ovipositional period was a single day, indicating that newly emerged females were reproductively mature. The greatest number of eggs was laid on the first night after mating (Fig. 3). On the 2nd night, cumulative eggs per female reached 79.2% of the total, which were about 10,000 eggs on average. Then the number of eggs laid per day abruptly decreased and no eggs were laid on the 8th night. The total number of eggs laid per female was positively correlated with the mesonotum length (Kendall rank correlation coefficient $\tau = 0.6$, $p < 0.001$) (Fig. 4) but not with longevity ($\tau = 0.124$, $p > 0.1$). There was no rank correla-

Table 1. Longevity, total no. of eggs oviposited and oviposition periods of *X. ceramica* females (n = 15)

	Mean ± 95% Confidence Intervals	Range
Preoviposition days	1	
Oviposition days	4.6 ± 0.9	2–7
Longevity (days)	7.0 ± 0.7	5–9
Total no. of eggs (oviposited/female)	12,489.4 ± 2,248.9	3,666–21,094

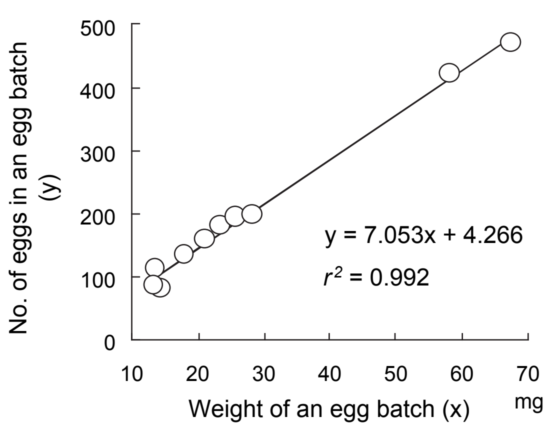

Fig. 2. Relationship between the numbers of eggs (y) and the weight (x) of an egg batch arbitrarily selected

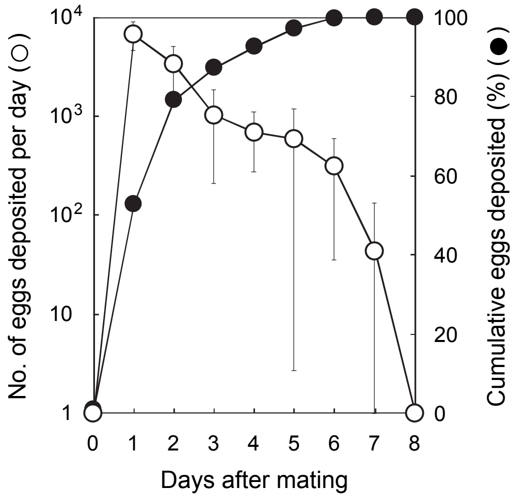

Fig. 3. Oviposition schedule of *X. ceramica*
All females (n = 15) mated on the first night after emergence. Vertical lines show 95% confidence interval.

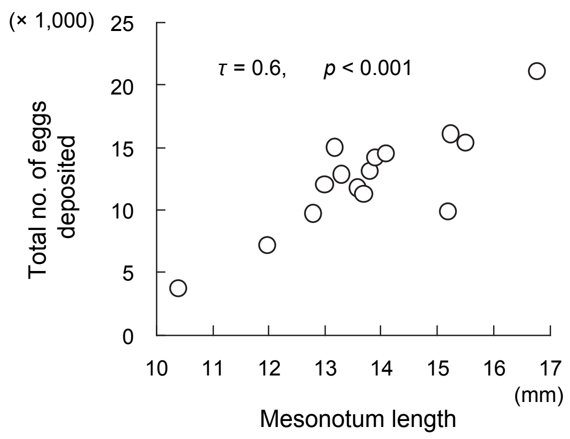

Fig. 4. Relationship between the length of female mesonotum and the total number of eggs deposited

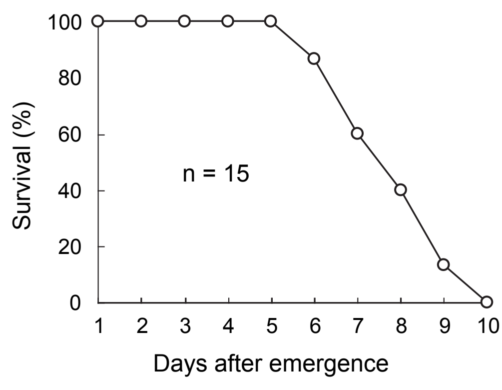

Fig. 5. Survival of mated females of *X. ceramica*

tion between the mesonotum length and longevity (τ = 0.019, $p > 0.1$). No mated female died before the 5th day after emergence, and survival rate abruptly declined thereafter (Fig. 5).

3. Oviposition in the field

In total, 10 egg masses were detected in 7 out of 100 trees examined. Only one egg mass was found in each of 5 trees, while 2 and 3 egg masses were in the other 2 trees, respectively. Fifty percent of egg masses were found beneath the scales of bark (Fig. 6, A) and 30% were both

Fig. 6. An egg mass (arrow) detected after removing the scales of bark (A), and an ovipositing female in nature on a teak trunk, dropping eggs attached in a string (arrow) to the ground (B)

beneath the scales of bark and in crevices adjacent to the scales (Fig. 7). In the egg masses beneath the scales, eggs were tidily arranged. Two small lumps of eggs were laid exposed on the surface of bark, one of which was predated by *Crematogaster* ants when found. Fifty percent of egg masses were laid at more than 3 m height from the ground, and 80% were more than 2 m from the ground (Fig. 8). No egg was found on the ground around tree bases. Unfortunately, we failed to count the number of eggs in each egg mass due to rotting of eggs in sealed containers.

At a 9-year-old stand in the Maegar Seed Orchard, one ovipositing female in nature resting on a teak trunk bearing smooth trunk bark at the height of 120 cm from the ground was observed periodically dropping her eggs to the ground around 21:00 h (Fig. 6, B). The number of eggs collected from the ground was 80 in total, which were single eggs or 2 to 11 eggs attached in a string. Her abdomen was slender, suggesting that she had already deposited a considerable number of eggs.

4. Larval behaviors on cut logs and living teak trunks

On average, 6.6% of the hatched larvae stayed on the logs, while the fate of 93.4% was unknown. The distribution of entry holes by the larvae 10 days after hatching is shown in Fig. 9. Of the larvae that stayed on the logs, 80.2 ± 7.8% (mean ± S.E.) bored into the logs, with 62.6%

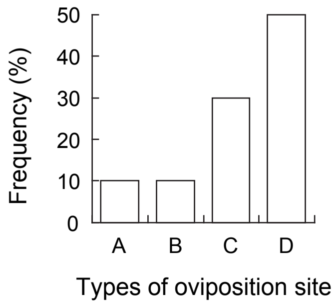

Fig. 7. Oviposition sites of *X. ceramica*
A: on bark; B: in the crevices of bark; C: beneath the scale of bark and in the adjacent crevice;
D: beneath the scale of bark.

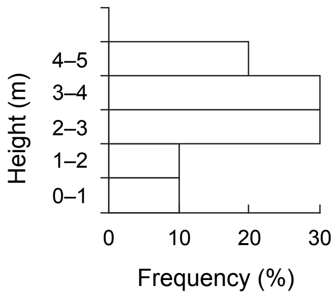

Fig. 8. Vertical distribution of egg masses on a teak trunk

on a lower part and 17.6% on a higher part of the log than the releasing point. On average, 19.8% of the staying larvae were caught on the sticky paper at the bottom of the tree, whereas no larvae were caught at the top. These trapped larvae are suggested to disperse by walking from the log.

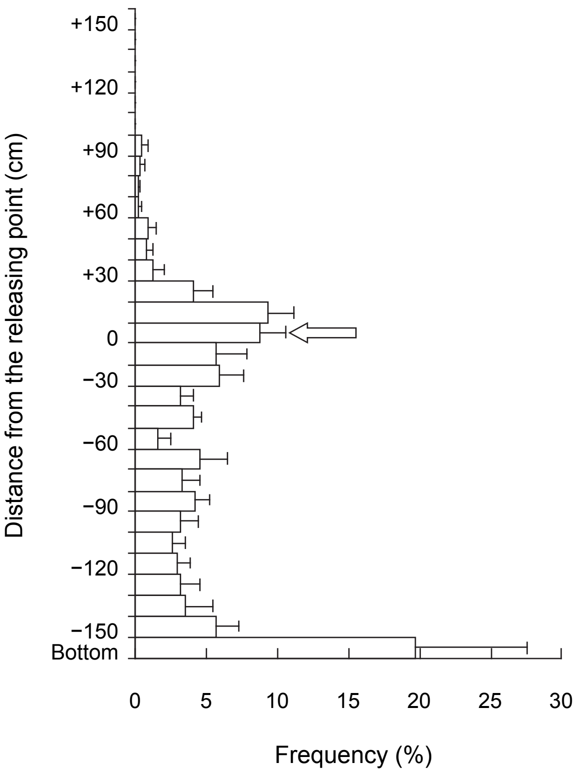

Fig. 9. Vertical distribution of entry holes of larvae that stayed on a teak cut log

The white arrow indicates the releasing point of egg mass at hatching. On the y-axis, the distances upwards from the releasing point (zero) are designated as + and those downwards as −. The horizontal lines show standard errors.

Seasonal changes in the vertical distribution of larvae on living teak trees and in the frequency of larvae that settled in particular boring sites are shown in Fig. 10. Through all months, the larvae were mostly distributed below the releasing point (3 m height from the ground), especially in the lowermost 0–2 m part of the trunk. For example, 60.2% (n = 183) of larvae were observed boring in the lowermost 0–2 m part on May 10. On June 10, there were no larvae that bored at the same site as in the previous month even in the lowermost 0–2 m part of the trunk. On July 10, 37.5% of surviving larvae remained in the same boring sites as in the previous month, then that percentage rapidly increased to 78.6% in August. All larvae settled down in particular boring sites in September, and then no larvae changed the boring site thereafter. Finally 75% of larvae (6/8) settled down in the lowermost 0–2 m part of the trunk.

Discussion

1. Emergence pattern

Emergence monitoring in 1991 and 1992 indicates that the emergence of TBB adults only occurs from late February through March in northern Thailand. The same pattern of emergence was reported in 1989 at the same locality as our monitoring site and it was shown that the emergence ended within March[6]. In Myanmar, adults begin to fly in late February in the south, while in May in the north[3], where the dry season generally ends in May. These facts indicate that TBB adults emerge around the end of the dry season or just prior to the beginning of the rainy season. On the other hand, quite different emergence was observed in 1993. It might have been caused by unseasonable heavy rainfall in December 1992, which interrupted the dry season widely in northern Thailand and likely caused heavy mortality of TBB. The precipita-

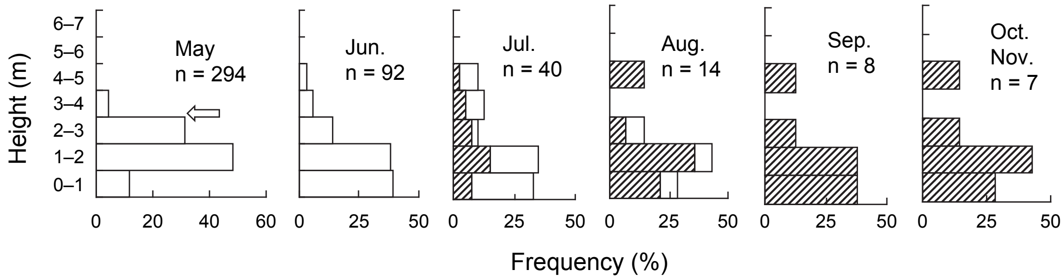

Fig. 10. Seasonal changes of vertical distribution of larvae on living teak trees and of larvae that settled down in particular boring sites

Shaded bars indicate the larvae that remained in the same boring site as in the previous month.
The arrow in May indicates the trunk height where egg masses at hatching were released.

tion in the month was 94.2 mm at the Teak Improvement Center, Ngao, although it is usually very small as exemplified by 2.4 mm in 1990 and 0.3 mm in 1991. In this center, more than 50% of the moths, which were probably at mature larval or prepupal stages in December, could not emerge as the openings of beeholes were blocked by the new lobes of callus due to the resumed cambial growth (unpublished data, 1993). It is known that cambial growth of trees is very responsive to environmental stresses, hence it often stops during droughts and resumes after a rain[12]. Therefore, the emergence of TBB seems to be affected by unusual rain during the dry season in Thailand.

2. Oviposition behavior

The fecundity of TBB has not been clearly studied so far. It has been only mentioned that the female laid thousands of eggs, up to 50,000[3], and captive females laid from 300 to 600 eggs in the course of 4–6 days[2]. Our study showed that females were able to lay from 3,000 to 20,000 eggs, which was positively correlated to their body size. As for oviposition schedule, it has been only known that egg-laying by captive females commences on the second day after emergence and continues until death[2]. However, it is not clear whether those reported females were mated or unmated. The results in the present study show that the female begins to lay eggs on the first night after mating and lays about 80% of the total eggs by the second night, and only a small number of eggs are laid thereafter. Females of TBB thus lay most of their eggs in a few days after mating.

So far no egg of TBB has been detected in the field in spite of careful searches by researchers[1,2]. Based on the habits of other Cossidae, it has been only assumed that eggs of TBB are laid in cracks or under scales of bark on the tree-trunk[2]. Our survey resulted in successfully locating egg masses in the field. This is the first record of eggs of TBB found in the field. The results suggest that the preferred oviposition site would be beneath the scales of bark. Thus trees bearing rough bark may be subject to oviposition. In teak, the bark becomes rough in well-growing trees and also at the part of the trunk where cambium grows actively (Kaosa-ard, personal comm.). Therefore, females seem to select well-grown trees in a stand for oviposition. Consequently, well-growing trees are more susceptible to attacks by TBB than slow-growing ones and therefore attacks are aggregated within a stand as reported[7]. Furthermore, in a tree the females seem to select a part of the trunk for oviposition where the bark is rough due to active cambial growth. Thus the trunk height of oviposition sites observed in the examined stand may be related to the vertical distribution of active cambial growth. It has been well documented that the location of maximum beeholing tended to move up the tree with increasing age[1–3,13]. This is probably because the part of the trunk bearing rough bark would move up the tree, corresponding to the change in vertical distribution of cambial growth with age in a man-made stand[11].

On the other hand, a female in nature was observed dropping her eggs to the ground around the base of a young teak tree with smooth trunk bark. This fact may indicate that the female would not lay her eggs on smooth trunk bark that has not developed crevices and scales yet; instead she would oviposit by dropping eggs to the ground. If so, larvae hatched on the ground probably would bore into the lowermost part of the trunk, where the attacks consequently become aggregated as reported in young stands[8].

The results on oviposition behaviors would be helpful to explain the characteristics of attack by TBB as discussed above. However, we need more data on oviposition sites in stands of different ages to fully understand the oviposition strategy of TBB in relation to tree growth.

3. Larval behavior

The result of the release of larvae on cut logs numerically showed that only a few percent of hatched larvae stayed on the logs and the others were missing. Most of the missing larvae may have dispersed by wind, since the hatching larva spins a long filament of silk that carries it away on a moderate breeze[3]. Released larvae showed positive geotaxis both on the cut logs and on the living teak trunks. This fact may indicate that larvae tend to move downwards from an oviposition site on the trunk. In contrast, it was supposed that it would be an advantage for larvae to move towards the crown, as this promised a more plentiful supply of food particularly in older trees[1]. However, it has not been confirmed whether larvae would move towards the crown or not. Our result clearly showed that larvae changed boring sites during young stages even in the lowermost 0–2 m of the trunk, where most larvae finally settled down and therefore seems the suitable place for successful larval development in the experimental trees. This wandering of larvae was thought to be occasioned mainly by lack of sufficient food (callus or sap) at their boring sites[3]. Therefore, it is considered that the suitable place for larval growth, where cambium grows actively, is localized in the tree trunk and its growth activity also changes with season progression. This may influence larval behaviors, causing the seasonal change of the rate of settlement and the upward or downward wanderings.

Implications for control

The results obtained in the present studies would be helpful to yield the ideas for control of TBB. Since females lay their eggs mostly beneath the scales of bark, it is necessary to reduce such oviposition sites in trees. Dry pruning to hasten occlusion of dead branches may be one of the methods for doing this because the bark around the base of branches becomes rougher and so is likely to supply suitable oviposition sites for TBB as in Fig. 6, A. At the same time the scales of bark should be scrapped off at least in well-growing trees in a stand. If females lay their eggs exposed on the rough surface of bark, the likelihood of being destroyed by predators probably will increase. In fact, one of two egg masses laid exposed on the bark was predated by ants in the investigated stand. The conservation of natural enemies, especially ants, would be also important as pointed out in a previous study[7]. From this point of view, forest fires that usually occur in the end of the dry season (also oviposition season of TBB) in teak stands should be controlled because they likely reduce the populations of natural enemies.

Acknowledgments

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References

1. Atkinson, D. J. (1936) A survey of the damage to teak timber by the beehole borer (*Xyleutes ceramica* Wlk.) throughout the main teak-bearing forests of Burma (Lepidoptera, Cossidae). *Ind. For. Rec.*, **2**(1), 1–98.
2. Beeson, C. F. C. (1921) The beehole borer of teak-A preliminary note on ecology and economic status of *Duomitus ceramica* Wlk. in Burma. *Ind. For. Rec.*, **8**(3), 229–333.
3. Beeson, C. F. C. (1941) The ecology and control of the forest insects of India and the neighbouring countries. Government Printing Office, India, pp.767.
4. Chalermpongse, A. et al. (1990) Surveilance of disease and insect damage in teak plantation in Thailand. *In* Proceedings of the IUFRO/FAO workshop on pests and diseases of forest plantations, Bangkok, Thailand, RAPA Publication No. 9, eds. Hutacharern, C. et al., FAO, Thailand, 224–229.
5. Choldumrongkul, S. & Hutacharern, C. (1990) Study on soil and properties of teak tree in relation to the number of beehole. *In* Proceedings of the IUFRO workshop on pests and disease of forest plantations, Bangkok, Thailand, eds. Hutacharern, C. et al., FAO, Thailand, 149–154.
6. Eungwijarnpanya, S. et al. (1994) Bionomics of teak beehole borer (*Xyleutes ceramica*) in northern Thailand: Emergence and response to light trap of adult moth. *Thai J. Agric. Sci.,* **27**, 1–8.
7. Gotoh, T. et al. (2002) Strategies for the management of the teak beehole borer, *Xyleutes ceramicus* (Walker) (Lepidoptera: Cossidae) in Thailand. *In* Proceedings of the IUFRO/FAO workshop on pest management in tropical forest plantations, Chanthaburi, Thailand, FORSPA Publication No. 30, eds. Hutacharern, C. et al., FAO, Thailand, 99–103.
8. Gotoh, T., Kotulai, J. R. & Matsumoto, K. (2003) Stem borers of teak and yemane in Sabah, Malaysia, with analysis of attacks by the teak beehole borer (*Xyleutes ceramica* Wlk.). *JARQ*, **37**, 253–261.
9. Hutacharern, C. & Tubtim, N. (1995) Checklist of forest insects in Thailand. Office of Environmental Policy and Planning, Ministry of Science Technology and Environment, Bangkok, pp.392.
10. Kaosa-ard, A. (1986) Teak (*Tectona grandis* Linn. f.) in ASEAN, a survey report. ASEAN/CANADA Forest Seed Centre, Saraburi, Thailand, pp.60.
11. Kozlowski, T. T. (1971) Growth and development of trees. Academic Press, New York, pp.514.
12. Kramer, P. J. & Kozlowski, T. T. (1979) Physiology of woody plants. Academic Press, New York, pp.811.
13. Maeto, K. & Eungwijarnpanya, S. (1994) Density and spatial distribution pattern of current emergence holes of the teak beehole borer, *Xyleutes ceramica,* in northern Thailand. *Thai J. Agric. Sci*., **27**, 83–95.
14. Sokal, R. R. & Rohlf, F. J. (1995) Biometry, 3rd edition. W. H. Freeman and Company, New York, U.S.A., pp.887.
15. Tee, B. (1995) Teak in Sabah -A sustainable agroforestry. SEJATI Sdn. Bhd., Kota Kinabalu, Sabah, Malaysia, 1–77.
16. Wood, H. (1993) Teak in Asia, proceedings. FORSPA Publication No. 4, ed. Wood, H., FAO, Bangkok, pp.126.