

Research Article

Attraction of *Tomicus yunnanensis* (Coleoptera: Scolytidae) to Yunnan Pine Logs with and without Periderm or Phloem: An Effective Monitoring Bait

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The Yunnan pine shoot beetle, *Tomicus yunnanensis* Kirkendall and Faccoli (Coleoptera: Scolytinae) is an important pest of Yunnan pine (*Pinus yunnanensis* Franch) in China. Experiments with host log baits were done to develop a pest monitoring system using host tree kairomone. Five Yunnan pine logs (each 10–15 cm diam. × 30-cm long) in a trap-log bundle were treated by peeling periderm (outer bark) off to expose the phloem, and half of each log was covered with sticky adhesive to capture any attracted adult beetles. Significantly, more beetles were attracted and caught on the periderm-peeled logs (ca 30 beetles/m² log surface/day) than on untreated control logs with adhesive (ca 2.5/m²/day). No significant differences were observed between catches on logs taken from lower or upper halves of Yunnan pines. *T. yunnanensis* flies mostly during the afternoon according to trap catches throughout the day. Attraction to the periderm-peeled logs decreased considerably when they were peeled further to remove the phloem, indicating phloem volatiles play a role in selection of the host by the beetle. The readily-available log baits appear useful for monitoring pine shoot beetle populations in integrated pest management programs.

1. Introduction

Tomicus yunnanensis (Coleoptera: Scolytinae) is a newly discovered and aggressive species of pine shoot beetle [1, 2]. It was confused with *T. piniperda* (L.) in the past [1–3]. Recent studies show there are clear morphological, genetic, and ecological differences between these two species [2–4]. Compared with *T. piniperda*, *T. yunnanensis* is more harmful because it not only causes great growth losses, but also kills healthy pines by mass attack [4–6]. It has caused extensive mortality of Yunnan pines, *Pinus yunnanensis* Franch, in Yunnan province of China [1, 7]. Since the 1980s, more than 200,000 ha Yunnan pine forests have been killed [3, 4, 7, 8].

T. yunnanensis attacks trunks during maturation feeding in Yunnan province [5, 7]. Trunk attacks last six to seven

months from December to May, and peak attacks occur from January to March. Attacks on trunks begin in the crown and then spread down the bole. New adults fly to the shoots starting in March, the peak flight emerging in mid June. Maturation feeding lasts six to eight months [3, 5, 7, 8].

The extensive damage by *T. yunnanensis* indicates that as in other pine systems, effective monitoring and control are necessary [9–11]. However, there are no effective methods to manage the insect so far. It is reasonable to suspect there may be plant compounds from Yunnan pines that are attractive [7, 8, 12]. However, it is not known whether the beetles use a kairomone of Yunnan pines to locate hosts. The most popular method in the past has been to use trap log bundles to see if they are attractive to the beetles. This method is simple to try, but requires detection of odor signals (kairomone) from

host or associated organisms that can be difficult to observe with catches of beetles using many logs [8, 13, 14]. Our objective was to design experiments that tested whether Yunnan pines release an attractive kairomone from various periderm- and phloem-peeled bait logs that could serve as an effective method for monitoring and potential control of *T. yunnanensis*. The research should provide methods that avoid unnecessary work and improve bait log efficiency [15, 16].

2. Materials and Methods

2.1. Study Site Conditions. A series of experiments were conducted in a 300 ha plantation of Yunnan pines located on the mountain near Qujing city in Yunnan province (25° 14' N, 103° 50', and 1700–1800 m above sea level). The field site mainly consisted of Yunnan pines, *Pinus yunnanensis* L., and a small proportion (<10%) of broad-leaved trees. Most of the Yunnan pines were infested with *T. yunnanensis*. The trees were 30–45 years old and ranged from 10–15 m in height and 10–15 cm in diameter.

2.2. Experimental Design. Two experiments were conducted from December to February in 2006 and 2007. In the first experiment, to avoid any sex pheromone effects, six healthy Yunnan pines were cut whose trunks were free of bark beetle attacks (no obvious beetle entrance holes). All the tree trunks were cut into 30-cm long logs. Among all the logs, 30 cut logs were randomly selected and the surface area of each log measured, then the periderm (outer bark) of the logs was peeled off leaving the phloem exposed (Figure 1(a)), and every five treated logs were placed in a trap log bundle. Another 30 cut logs were treated the same, but the phloem was also peeled from the logs (Figure 1(b)). The last 30 cut logs had only their surface area measured and were not peeled (Figure 1(c)). Half the surface area of each log (15 cm) was covered with sticky adhesive supplied by Hebei Academy of Forestry to catch any bark beetles that landed. Finally all the cut logs in the 18 bundles were randomly hung at about 1.5–1.7 m height in trees. The distance between one trap log bundle to another was about 100–120 m. In addition, six healthy Yunnan pines were randomly chosen and the trunk periderm was peeled off for 1.5 m of the trunk upward beginning 0.6 m above the ground, but the phloem was left in good condition, then half of the peeled trunk surface was covered with the adhesive every other 15-cm height interval (Figure 1(d)). All six trees remained standing. The distance between each of these trees was also about 100–120 m. The trap catches of the bark beetles were collected daily and species distinguished with a binocular microscope. This experiment was repeated monthly for three months (December to February in 2006 and 2007); with results of all months pooled to obtain a daily mean trap catch.

In the second study, four healthy Yunnan pines were cut down, each tree divided into two sections from the middle (lower half and upper half). Then a 1.5 m long log was cut from each section, and all the periderm peeled off with the phloem remain in good condition. Finally, each log was divided into five 30 cm long bolts and these were put in one

trap log bundle; half the surface of each piece was covered with adhesive. The bundles from the top-half section and the bottom-half section were arranged in pairs (to give almost equal diameter) and hung up in trees at 1.5–1.7 m height. The distance between each trap log bundle was about 100–120 m. The experiment was replicated each of three months for two years as in the first experiment. The trap catches of the bark beetles were collected each day and species distinguished with a binocular microscope.

2.3. Data Presentation and Analyses. Data were checked for normality and presented as mean \pm standard error. Variance analysis (ANOVA) was conducted with SPSS 11.5 (SPSS Inc., Chicago, IL, USA).

3. Results

The trapping efficiency of log bundles for *T. yunnanensis* was greatly affected by the log treatment method (Figure 2). Logs with the periderm peeled off and the phloem left were most attractive to *T. yunnanensis*, attracting roughly 30 *T. yunnanensis* per day per square meter log surface. There were significant differences between the trap catches of *T. yunnanensis* among the other log treatment methods ($P < 0.05$, Tukey's multiple comparison). The other two methods of treating the trap log bundles attracted much fewer *T. yunnanensis*. However, the logs with both periderm and phloem peeled off attracted slightly, but not significantly, more *T. yunnanensis* than the logs not peeled. The uncut pine trees attracted the fewest *T. yunnanensis*.

Dissection of the trunk (results not shown) indicated that the distribution of the entrance holes of *T. yunnanensis* is mainly in the mid and upper sections of Yunnan pine trees. Whether this pattern is affected by variations in a kairomone of Yunnan pine is unknown. To investigate this, logs from different parts of Yunnan pine trees were compared for attraction of *T. yunnanensis*. We found that logs from the upper half of Yunnan pine trees attracted a little more *T. yunnanensis* than sections from the lower half of the tree, but there was no significant difference ($P < 0.05$, Tukey's paired-samples test, Figure 3).

The trap catches of *T. yunnanensis* during the day show that *T. yunnanensis* was trapped in the afternoon, the peak capture rate occurred from 14:00 to 18:00, while a few were trapped from 7:00 to 14:00. The peak time of capture was strongly affected by weather conditions; occurring a little earlier or later, or not at all under poor weather conditions. Figure 4 shows results under good weather conditions.

4. Discussion

The periderm is important to trees; the outer bark slows the release of water and organic volatiles from inside the tree. Once logs were peeled, their volatiles were released in much larger amounts, allowing the peeled logs to attract more *T. yunnanensis* than the unpeeled ones. Yunnan pine bark is known to contain many different monoterpenes (primarily α -pinene and 3-carene) somewhat similar to Scots pine [17].



FIGURE 1: (a) Trap log bundles with periderm peeled off. (b) Trap log bundles with periderm and phloem peeled off. (c) Intact (not peeled) trap log bundles. (d) Standing Yunnan pine tree with periderm peeled off and every other 15 cm section covered with sticky adhesive (Qujing, Yunnan, China).

These volatiles may comprise a kairomone of various monoterpenes that was shown attractive to another *Tomicus* species, *T. piniperda*, in Sweden that colonizes Scots pine [12]. Interestingly, the peeled logs that retained the phloem were much more attractive to *T. yunnanensis* than the logs peeled of both periderm and phloem. This is surprising since monoterpenes should exude from the xylem tissues and cause attraction. However, this was not the case. Observations during the experimental study revealed that all the beetle galleries were found in the phloem, which means the phloem is the main food of the beetle, as in most bark beetles [18, 19]. The results suggest the odors released from this part of the tree are used as the kairomone by the beetles when searching for food. The phloem is the tree's main transport channel of photosynthetic nutrition. Perhaps the energy from phloem is needed to continue releasing resin (and kairomone). In any case, the

experimental results from the logs treated by peeling off the phloem shows that once the log has lost its phloem, its ability to attract beetles is greatly weakened.

Trunk attacks by *T. yunnanensis* are a major cause of tree mortality in Yunnan province [20]. It is reasonable to use kairomone of Yunnan pine trees to monitor and aid in control of the beetles. Natural kairomone would be expected to be as effective as the best synthetic blends that require much research to elucidate. As an alternative to synthetic baits, one of the most popular methods is to use trap log bundles to monitor population levels of beetles. This method is simple and uses readily available resources, but does require significant labor and many logs. We peeled logs to improve the quantities of volatile chemical compounds released, making it possible to use fewer logs and trap more bark beetles. In addition, the peeled logs make it easier to count beetles that

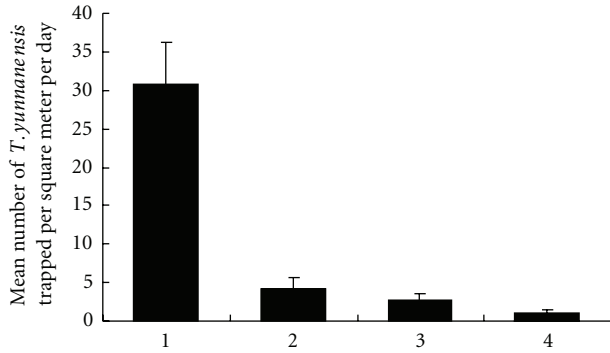


FIGURE 2: Daily mean trap catches (\pm SE, $N = 180$) of *T. yunnanensis* attracted to: (1) periderm peeled logs, (2) periderm and phloem peeled logs, (3) intact (unpeeled) logs, and (4) standing periderm-peeled Yunnan pines (Dec.–Feb. 2006, 2007; Qujing, Yunnan, China).

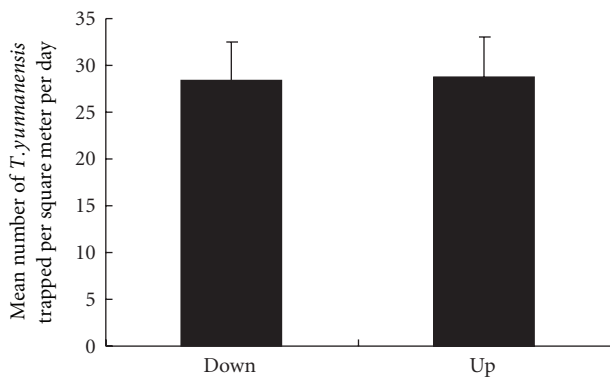


FIGURE 3: Daily mean trap catches (\pm SE, $N = 180$) of *T. yunnanensis* on logs from lower-half (Down) and upper-half (Up) sections of Yunnan pines (Dec.–Feb. 2006, 2007; Qujing, Yunnan, China).

are attracted and caught, especially when the surface of the peeled logs is covered with sticky adhesive. Our experimental results show the logs peeled of periderm (outer bark) trapped the most *T. yunnanensis*. While the standing trees peeled in the same way attracted the fewest bark beetles. The standing trees should have not only had constitutive defenses but also inducible defenses [21–24]. The periderm was the most important defensive factor that protected the trunks. When the periderm of trees was peeled off, the constitutive defenses lost effectiveness to some extent, but this damage activated the strong inducible defenses [23]. If the trees were cut down, they lost the inducible defenses. The periderm is important because it not only retards water loss from trunks, but also prevents volatiles from rapidly evaporating from the phloem's resin canals. When the periderm was peeled off, the release rate of volatiles likely increased greatly and enhanced attraction. Logs which were not peeled trapped only a few bark beetles as did the logs peeled to remove phloem. This may happen because most of the kairomone came from phloem, so when the phloem was lost, the attractive ability was reduced, indicating that the phloem was the most important source of the kairomone. However, whether the kairomone is synthesized in phloem is uncertain.

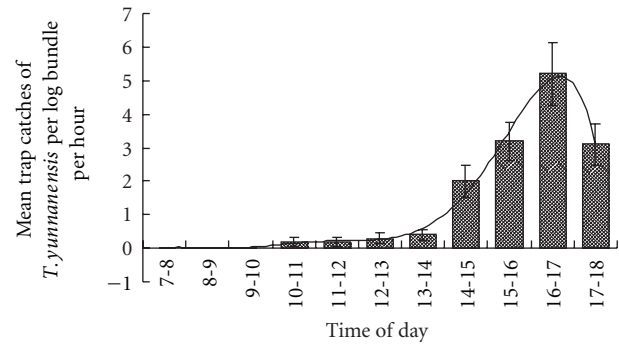


FIGURE 4: Mean trap catches (\pm SE) per hour of *T. yunnanensis* on periderm-peeled log bundles during the day (Dec.–Feb. 2006, 2007; Qujing, Yunnan, China).

Most *T. yunnanensis* were trapped in the afternoon; maybe because *T. yunnanensis* was more flight active in the afternoon. Consequently, the afternoon is the best time to study bark beetle behavior in regard to host selection and colonization. In nature, most of the *T. yunnanensis* attacks are found in the top section of the tree [25] but when we used different sections of the tree to attract and trap the beetle, there were no significant differences among the sections. Thus, there appears to be no obvious differences in kairomone release among the different sections from the lower and upper halves of the tree.

Here we present an efficient method to determine whether the kairomone of the host trees can be used to trap pest bark beetles, and whether it is possible to produce attractive baits from the host tree. Pine logs peeled of periderm as baits are easier and more effective compared with traditional log bait methods that use logs with intact bark.

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