Adult Density of the Sugi Bark Borer, *Semanotus japonicus*
LACORDAIRE (Coleoptera: Cerambycidae), in Damaged
Stands of Japanese Cedar, *Cryptomeria japonica* D. DON.¹

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Adult density of the sugi bark borer, *Semanotus japonicus* LACORDAIRE (Coleoptera: Cerambycidae), was investigated in 60 planted Japanese cedar *Cryptomeria japonica* D. DON. stands in Mie, Kyoto, Nara and Osaka Prefectures, central Japan. The percentage of damaged trees increased with stand age up to 22 years. Stands which were 10- to 17-years old or with mean tree diameters of 6 cm to 17 cm yielded the highest numbers of adults.

Key words: *Semanotus japonicus*, *Cryptomeria japonica*, adult density, damaged trees, stand age, tree size

INTRODUCTION

The sugi bark borer, *Semanotus japonicus* LACORDAIRE (Coleoptera: Cerambycidae), attacks the trunk of living Japanese cedar, *Cryptomeria japonica* D. DON. (KOBAYASHI, 1985). The quality of cedar timber is reduced considerably due to larval feeding and subsequent invasion of wood rotting fungi, known as "hachikami" (KOBAYASHI, 1980). Heavily infested cedar stands are found throughout Japan, with the exception of Hokkaido (KOBAYASHI and SHIBATA, 1985).

The spatial distribution of attacked trees and the relationship between infestation and environmental factors have been intensively analyzed during the last 10 years (e.g. NISHIMURA, 1983; SHIBATA, 1988). SHIBATA (1983, 1986) estimated adult density by a mark-release-recapture method, and FUJITA et al. (1990) and ITO and KOBAYASHI (1991) showed annual changes in adult emergence holes on the trunks of trees in young cedar stands. Little else is known about adult density in infested cedar stands.

SHIBATA et al. (1986) developed a monitoring and sampling method for cedar stands, using a sticky trap banding method. Since 1985, we have sampled the adult population of the sugi bark borer by this method in 60 cedar stands in Mie, Kyoto,

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Nara and Osaka Prefectures, central Japan. This paper describes adult density in cedar stands of various ages, diameters and damage levels.

MATERIALS AND METHODS

Study stands. This study was carried out in 5 Japanese cedar stands in Mie Prefecture, 7 in Kyoto Prefecture, 13 in Osaka Prefecture and 35 in Nara Prefecture during 1985 and 1989. All study stands were man-made forests at elevations that were usually lower than 200 m, where bark bores tend to concentrate (SHIBATA, 1988). Stand age (AGE) was determined by referring to historical records and/or by counting the annual rings of stems after cutting trees. Mean diameter of the cedar stand was calculated by measuring the diameter at breast height (DBH) of each sampled tree.

Sampling adult population. Collecting bark borer adults, even in severely infested stands, was difficult until SHIBATA (1983) devised a band-trapping method. This technique was later modified using sticky bandages, i.e., the sticky trap banding method (SHIBATA et al., 1986), in which the trunk of each examined tree was wrapped with a sticky bandage (width: 8 cm). In our study, 10 to 195 trees (mean sample: 64) in stands were bandaged at 1.2 m above the ground. Bandages were put in place from late February or early March to mid-May. This period fully covered the flight season of adults (mid-March to early May) in this district (SHIBATA, 1986). The number of adults adhering to the bandages was counted on each tree. This number reflects the number of adults which emerged in the stand (SHIBATA et al., 1986), so the adult density in the stand (ADT) was represented by the number of adults per sampled tree.

Definition of damaged trees. When the diameter of each sampled tree was measured, the trunk surface within 2 m of the ground was carefully examined. Damaged trees were then defined as ones on which adult emergence hole(s) and/or callus formation(s) around larval galleries were observed. Percentage of the damaged trees in the cedar stand (DMG) was estimated as the ratio: (number of damaged trees)/(number of sampled trees). DMG was transformed to $\arcsin \sqrt{\text{DMG}}$ prior to use in statistical analysis.

RESULTS

Frequency distributions of stand age (AGE), mean diameter at breast height (DBH), percentage of damaged trees (DMG) and adult density (ADT) in the study stands are shown in Fig. 1. AGE ranged from 5- to 27-years old, and DBH from 2.9 cm to 20.2 cm. DMG was 0% to 90%. Nine stands (15.0%) had 0% damage and 33 stands (55%) were below 20%. ADT was 0 to 3.1. No adults were collected at 5 stands (9.8%).

There was a significant correlation between AGE and DBH (Fig. 2), suggesting that the DBH increased with AGE ((DBH)=5.280+0.440 (AGE), $r=0.726$, $p<0.01$). Furthermore, we defined 34 cedar stands above the regression line as faster-growing stands, and 26 stands under the line as the slower-growing ones.

The relations of DMG to AGE in the faster-growing and the slower-growing stands are shown in Fig. 3. The following curves of quadratic polynomials for the stands were observed.

Faster-growing cedar stands:

$$(\arcsin \sqrt{\text{DMG}}) = -9.640 + 4.871 (\text{AGE}) - 0.110 (\text{AGE})^2 \quad (R=0.565)$$

Fig. 1. Frequency distributions of stand age, tree size, damage level, and *S. japonicus* adult density in 60 stands of *C. japonica*. A: stand age (AGE), B: mean diameter at breast height (DBH), C: percentage of damaged trees (DMG; open bar: no damage), D: adult density ADT; open bar: no adults).

Fig. 2. Relationship between stand age (AGE) and mean diameter at breast height (DBH) in 60 *C. japonica* study stands. Solid and open circles show faster-growing and slower-growing stands, respectively.

Slower-growing cedar stands:

$$(\arcsin \sqrt{\text{DMG}}) = -28.836 + 6.156 (\text{AGE}) - 0.140 (\text{AGE})^2 \quad (R=0.697)$$

These relationships suggested that DMG increased with AGE and then peaked at the age of 22 years. Though the fitted curves decreased above 22 years, DMG would become constant because most insect-attack marks remain on the surface of tree trunks. DMG tended to be continuously higher in the faster-growing cedar stands than in the slower-growing ones. Furthermore, the damage tended to occur earlier in the faster-growing cedar stands.

There was no significant correlation between AGE and ADT ($r = -0.081$, $p > 0.05$, Fig. 4). However, adult density tended to become high at 10-year old stands and low at 17-year old and older stands. More adults were collected in 10- to 17-years

Fig. 3. Relationships between stand age (AGE) and percentage of damaged trees (DMG), in 60 *C. japonica* study stands. Solid and open circles show faster-growing and slower-growing stands, respectively. Solid and broken lines are fitted curves for faster-growing and slower-growing stands, respectively.

Fig. 4. Relationship between stand age (AGE) and *S. japonicus* adult density (ADT), in 60 *C. japonica* study stands. Solid and open circles show faster-growing and slower-growing stands, respectively.

Table 1. Adult density of *S. japonicus* in faster-growing and slower-growing stands at each tree age class of *C. japonica*

Tree age class (AGE)	Mean density of adults per tree (ADT)	
	Faster-growing stands	Slower-growing stands
5- 9 yr	0.14*(11) ^a	0.01*(7)
10-15 yr	0.78 (16)	0.47 (12)
16-27 yr	0.09 (7)	0.15 (7)
Total	0.46 (34)	0.27 (26)

* Significant at 0.05% (*t*-test).

^a Number of cedar stands.

Fig. 5. Relationships between mean diameter at breast height (DBH) and *S. japonicus* adult density (ADT), in 60 *C. japonica* study stands. Solid and open circles show faster-growing and slower-growing stands, respectively.

old stands. Table 1 shows that there is a significant difference in ADT under 9-years old cedar stands between the faster-growing stands and the slower-growing ones, suggesting that the attacking adult density is higher in the former than in the latter when the stands are young.

Furthermore, there was also no significant correlation between DBH and ADT ($r = -0.112$, $p > 0.05$, Fig. 5), but clearly more adults were collected in stands where DBH was 6 cm to 17 cm.

DISCUSSION

In this study, the majority of sugi bark borer adults were collected in Japanese cedar stands of ages between 10 and 17 years old. FUJITA et al. (1990) observed that a borer population became established in a young cedar stand 8 years after planting and reached a peak density 5 years later. ITO and KOBAYASHI (1991) also observed population establishment in a young cedar stand 5 years after planting, which reached a peak after 11 years and then declined rapidly. Population trends of the bark borer in cedar stands are characterized by a transient outbreak which occurs in young stands (ITO and KOBAYASHI, 1991). Although our study did not follow fluctuations of the borer population in the same stand, the pattern observed was consistent with the population trends observed in other studies.

ITO and KOBAYASHI (1991) suggested that the abundance of the bark borer in young cedar was limited by the availability of the larval food resource, especially in the faster-growing trees. That is, at the beginning of the outbreak in a young stand, borers initially utilize the faster-growing trees, resulting in an increase of adult density. These suitable trees are eventually exhausted as food sources, resulting in a decrease of adult density. In this study, the adult density in the young stands was higher in the faster-growing stands than in the slower-growing ones. Thus, the mean diameter of cedar stands relative to their age might be also an important factor to determine adult borer density because it reflects the growth rate and proportion of faster-growing trees within stands. It is well known that attacking adults of the sugi bark borer prefer to hide themselves in shaded locations on the trunks such as the bark crevices in which

they lay their eggs (KOBAYASHI and SHIBATA, 1985). Faster-growing cedar trees might have rougher tree trunk surface than others, presenting suitable habitats and oviposition sites for adults. This might be one of the reasons why the faster-growing trees and/or stands suffer particularly severe infestations.

The percentage of damaged trees increased with age up to 22 years in cedar stands and then stabilized in this study. After the borer population became established in a young cedar stand, the occurrence of newly damaged trees⁶ increased slightly during the first several years, increased drastically during peak years of the borer population, and then decreased in correspondence with the decrease of adult density (ITO and KOBAYASHI, 1991). The annual accumulation of damaged trees has been described as a sigmoidal curve (ITO and KOBAYASHI, 1991). The relationship between the percentage of damaged trees and stand age in 60 cedar stands also agreed with their study. This pattern is due to the damage features of this insect. The damage on the cedar trunk—adult emergence hole(s) and/or callus formation(s) around larval galleries—remains on the tree trunk surface and most of damaged trees continue to grow. Therefore, the cumulative number of the damaged trees in a stand increases annually. Thus, the percentage of damaged trees in 60 cedar stands would increase with stand age, reflecting the transient outbreak of this insect.

The percentage of damaged trees tended to be continuously high in the faster-growing cedar stands in this study. Furthermore, it has been reported that faster-growing cedar trees in the stand were vulnerable to the borer (YAMADA, 1968; NISHIMURA, 1983; SHIBATA, 1986; ITO and KOBAYASHI, 1991). This is due to the preference of adults for faster-growing trees and/or stands as oviposition sites. This also suggests that control procedures should take this into account, even if stand ages are the same.

In integrated pest management programs against this borer, it is advisable to determine the mean diameter of cedar stands which adults can utilize. In this study, more adults were collected in stands where DBH was 6 cm to 17 cm. Thus, any treatment to prevent borer attacks needs to be applied only when the mean diameter of cedar trees is between 6 cm and 17 cm.

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⁶ In this case, damaged trees were defined only as ones on which emergence hole(s) were observed.

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