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Susceptibility of Forest Insect Pests to Sulfuryl Fluoride

2. Ambrosia Beetles

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Abstract: Five species of ambrosia beetles, *Xyleborus pfeili, Xyleborus validus, Xylosandrus germanus. Platypus calamus* and *Platypus quercivorus* were fumigated with sulfuryl fluoride at 5-11 doses for 24 or 48 hours at 15 ℃ to evaluate the susceptibility to sulfuryl fluoride. Dose-mortality data and Probit analysis data showed that *X. pfeili, X. validus* and *X. germanus* adults, and *P. calamus* and *P. quercivorus* larvae and adults were killed completely at doses of 15 g/m^3 or below for 24 hours. Low mortality ratios(35 % or below) were obtained on *X. pfeili* egg (19.0 % at 80 g/m^3), *X. validus* and *X. germanus* larvae(11. 1 % at 40 g/m^3) for 24 hours at 15 ℃, respectively, while the mortality for *X. pfeili* were 11.1 % at 40 g/m^3 and 23.1 % at 50 g/m^3 for eggs, 98.8 % at 50 g/m^3 for larvae, and 100 % at 20 g/m^3 for adults, respectively for 48 hours at 15 ℃. The *X. pfeili* eggs were the most resistant stage than other stages of the pests and it is very difficult for the eggs to estimate applied dose for attaining 100 % mortality at fumigation temperature of 15 ℃.
Key words: quarantine pests, *Xyleborus pfeili, Xyleborus validus, Xylosandrus germanus, Platypus calmus, Platypus quercivorus*, fumigation, sulfuryl fluoride, susceptibility

Introduction

Methyl bromide was listed as an ozone depleting substance in the Fourth Meeting of Montreal Protocol in November 1992. It was determined that the domestic production and consumption from 1995 was freezed at 1991 levels (TATEYA, 1993).

Japan imports more than 70 % of its domestic wood consumtion from foreign countries and the amount of the import reached to 22,651,000 m^3 in 1994. In plant quarantine inspection at the port of entry, forest insect pests of quarantine importance such as Scolytidae, Cerambycidae, Platypodidae, Curculionidae, Bostrychidae, Lyctidae, Anthribidae, Brentidae are often intercepted and they are mainly subjected to methyl bromide at timber yard and ship's hold covered with a tent. Approximately 55 % of methyl bromide is used for imported wood in Japanese quarantine (Yokohama Plant Protection Station, MAFF, 1995). It is, therefore, an urgent matter for Japanese quarantine to find out a new fumigant.

Sulfuryl fluoride has been used as structural fumigants since the 1950s (STEWART, 1957). This fumigant is easy to apply, nonflammable, and noncorrosive and it also offers high diffusion for rapid penetration and aeration (KENAGA, 1957; MEIKLE & STEWART, 1962). This fumigant was registered in the United States for use against various wood-infesting and household pests (USDA, 1985; Anonymous, 1992; 1993; THOMS & SCHEFFRAHN, 1994).

We here report results of the susceptibility of each stage of ambrosia beetles (*Xyleborus pfeili,*

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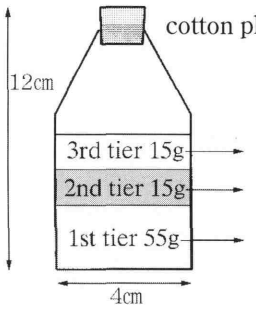
Xyleborus validus, *Xylosandrus germanus*, *Platypus calamus* and *Platypus quercivorus*) to sulfuryl fluoride fumigation, and to discuss the potential use for imported wood as a fumigant.

Materials and Methods

Test Insects

Xyleborus pfeili (RATZEBURG)

Adults were collected at Omaezaki in Shizuoka Prefecture in 1995. The adults were reared on a formulated diet (Fig 1) using procedures similar to those described by TAKEMORI et al.(1973). However, methods were modified by MIZUNO (in preparation), one of the authors. These ingredients were mixed and put in a glass bottle (115 ml capacity, 12 cm depth, 4 cm width). The pine resin was placed between the second and third tier to prevent spreading harmful microorganisms. The bottle was then sterilized at 120 ℃ for 60 minutes in autoclave. The adults were reared for 1-2 months at 24-27 ℃ for preparing desired stages of eggs, larvae, pupae and adults. The bottles containing each stage were then transport-



Sawdust (g)	Starch (g)	Dried yeast (g)	Graduate sugar (g)	Water (ml)
100	0	0	10	150
100	15	15	10	150
100	50	15	10	150

Fig.1 Rearing bottle and ingredients of artificial diet for *Xyreborus pfeili*

ed from Omaezaki office to the Research Division, Yokohama Plant Protection Station. These bottles were broken carefully and cylindrical shaped diet was wrapped by a piece of paper towel before testing.

Xyleborus validus EICHHOFF **and** ***Xylosandrus germanus*** (BLANDFORD)

Infested Japanese cedar logs (10 to 20 cm diameter) were collected at Ena, in Gifu Prefecture in 1995. They were stored until desired stages of larvae and adults were obtained and then provided for the test.

Platypus calamus BLANDFORD **and** ***P. quercivorus*** (MURAYAMA)

Infested oak (*Quercus crispula*) logs (10 to 20 cm diameter) were collected at Asahimura, Yamagata Prefecture in 1994 and 1995. They were stored until desired stages of larvae and adults were obtained, and infested logs were provided for the test.

Fumigation

Fumigation was performed in 30 liter fiber-glass chambers equipped with a gas applicator, an exhauster, ports for a gas collector, a manometer and a temperature probe. All species of the insect

were fumigated at 5-11 doses (5, 10, 15, 20, 25, 30, 35, 40, 50, 65, and 80 g/m^3) at 15 ℃ for 24 or 48 hours. Fumigation temperature of 15 ℃ was introduced to the test for being applied widely to imported wood fumigation with the exception of winter season. The methods for sulfuryl fluoride (purity; 99 % or more) application, gas concentration and temperature monitoring during fumigation and ventilation after fumigation were the same as described by SOMA et al. (1996).

Evaluation of Mortality

Fumigated artificial diet and logs containing each stage were removed from the chamber and stored at 25 ℃, 70 % R.H. until assessment of the mortality. The diet containing *X. pfeili* was broken to pieces. The mortality was evaluated by hatching for eggs and emergency for pupae every 2-3 days, and reaction by stimulating with a small paint brush at 1 to 5 days after for larvae and adults under microscope. The *X. validus* and *X. germanus* larvae and adults were evaluated by chopping the logs at 8-9 days after.

Data Analysis

Dose-mortality data were analyzed by the Probit procedure using FINNEY's formula (FINNEY, 1971). Linearity regression lines obtained from the statistical analysis were tested by the Chi-square test and fiducial limits were calculated using FIELLER's formula (FINNEY, 1971). The LD_{50}'s and LD_{95}'s were considered to be significant difference when their 95 % fiducial limits did not overlap. The Probit calculation was made by using a computer program (POLO-PC: LeOra Software, 1987).

Results and Discussion

The results of the Probit analysis and doses for 50 and 100 % mortalities for 5 species of ambrosia beetels are shown in Table 1. The Probit analysis for *X. pfeili* adults, *X. validus* and *X. germanus* larvae and adults, and *P. calamus* adults were not calculated because of high mortality ratios at relatively low doses used and shortage of appropriate data.

The *X. pfeili*, *X. validus* and *X. germanus* adults, and *P. calamus* larvae and adults were killed com-

Table 1. Estimated LD_{50} and LD_{95} values and doses for 50 % and 100 % mortalities against 5 species of ambrosia beetles fumigated with sulfuryl fluoride for 24 hours at 15 ℃.

Species	Stage	LD_{50}(95%FL) (g/m^3)	LD_{95}(95%FL) (g/m^3)	Required dose(g/m^3)	
				50%	100% mortality
Xyleborus	Egg	—	—	>80	
pfeili	Larva	26.8(20.2-32.4)	81.7(61.6-144.8)		>80
	Pupa	3.5(0.9- 6.0)	76.6(43.7-280.3)		>80
	Adult	—	—		10
Xyleborus	Larva	—	—	>40	
validus	Adult	—	—		5
Xylosandrus	Larva	—	—	>40	
germanus	Adult	—	—		5
Platyupus	Larva	3.2(1.8- 4.0)	8.4(7.0- 12.3)		15
quercivorus	Adult	4.2(3.0- 5.0)	9.2(7.7- 13.8)		15
Platypus	Larva	—	—		15
calamus	Adult	—	—		15

— : Probit analyses could not be calculated because of high mortality at low doses and low mortality at high doses and shortage of appropriate data.

pltetely at doses of 15 g/m^3 or below. Low mortality ratios (35 % or below) were obtained on *X. pfeili* egg (19 % at 80 g/m^3), *X. validus* and *X. germanus* larvae (11.1 % at 40 g/m^3), respectively, and the mortality of *X. pfeili* eggs were 28 % at 80 g/m^3, 32 % at 100 g/m^3, respectively. A 100 % mortality was not also obtained on *X. pfeili* eggs, larvae and pupae at a dose of as much as 80 g/m^3. These data show that larval, pupal and adult stages of the pests were more susceptible than egg stages, and that it could be clearly said that *X. pfeili* eggs were the most resistant stage in all stages of 5 species tested. These results were almost the same tendency of previous reports on studies of sulfuryl fluoride against termites (KENAGA, 1957; DOTY & WHITNEY, 1967; SU, 1990; SOMA et al., 1996). SOMA et al. (1996) conducted the susceptibility test for all stages of 7 species of forest insect pests (*Semanotus japonicus, Callidiellum rufipenne, Monochamus alternatus, Cryphalus fulvus, Ips cembrae, Phloeosinus perlatus, Shirahoshizo sp.*) to sulfuryl fluoride under the same conditions (for 24 hours at 15 ℃). They confirmed that *C. fulvus* egg was the most resistant stage (LD50 : 52.0 g/m^3; LD95 : 86.5 g/m^3) and they also reported that applied dose for attaining 100 % mortality would be requred as much as 130 g/m^3 or above. The *X. pfeili* eggs were more resistant than *C. fulvus* eggs to the fumigant. It is, therefore, very difficult for *X. pfeili eggs* to estimate applied dose for attaining 100 % mortality and for sulfuryl fluoride fumigation to be introduced in imported wood quarantine at fumigation temperture of 15 ℃.

Table 2 shows result of the mortality test for *X. pfeili* fumigated for 48 hours at 15 ℃. The mortality of each stage was 11.1 % at 40 g/m^3 and 23 % at 50 g/m^3 for eggs, 98.8 % for larvae and 100 % at 20 g/m^3 for adults, respectively. The mortality was higher than thouse obtained by 24 hours fumigation when

Table 2. Dose-mortality data for *Xyleborus pfeili* fumigated with sulfuryl fluoride for 48 hours at 15 ℃.

Species	Stage	n	Mortality (%)			
			20g/m^3	30g/m^3	40g/m^3	50g/m^3
Xyleborus pfeili	Egg	66	—	—	11.1	23.1
	Larva	508	91.1	90.4	97.6	98.8
	Pupa	94	100	100	100	100
	Adult	263	100	100	100	100

expouser time was extened to 48 hours from 24 hours at 15 ℃. These data may show that the larval and pupal stages exception for egg stage might be killed completely when fumigation is conducted at higher temperatures.

The ecology of ambrosia beetles in the xylem was that the adults culture microorganisms of "ambrosia" in their long tunnels and maintaine their long houses clean up dirt to pdoduct "ambrosia fungus" for feeding their hatched larvae (TAKAGI, 1967; TAKAGI, 1968; NOBUCHI, 1974). If the adults were killed by fumigation and their houses were not taken care by the adults, other harmful microorganisms would be enter into their houses for its pollution. Hatched larvae might not survive any more. Introduction of ecological viewpoint of ambrosia beetles might be one of development methods for the quarantine treatment. Further tests, therefore, must be conducted with higher fumigation temperatures or mixture gas with other fumigants for obtaining more efficacy against larvae and pupae of ambrosia beetls.

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和文摘要

フッ化スルフリルに対する木材害虫の感受性

2．アンブロシアビートル

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15℃、24時間及び48時間の条件下におけるフッ化スルフリルくん蒸に対するアンブロシアビートル（*Xyleborus pfeili*、*Xyleborus validus*、*Xylosandus germanus*、*Platypus quercivorus*、*Platypus calamus*）の感受性を調査した。

15℃、24時間くん蒸では、5種類の成虫とナガキクイムシ科の幼虫は15g/m^{3}以下で完全殺虫されたが、*X. pfeili*の卵は80g/m^{3}で19.0％、*X. validus*及び*X.germanus*の幼虫は40g/m^{3}で11.1％の殺虫率であった。しかし、*X. pfeili*を15℃、48時間でくん蒸した場合、卵は40g/m^{3}で11.1％、50g/m^{3}で23.1％、幼虫は50g/m^{3}で98.8％、成虫は20g/m^{3}で100％の殺虫率であった。フッカ化スルフリルくん蒸に対して最も耐性なのは*X. pfeili*の卵で、このステージを15℃下のくん蒸により100％殺虫できる薬量を推定することは困難である。

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