Effects of Certain Insecticides on *Lyctus brunneus* STEPHENS (Coleoptera : Lyctidae)

Takaaki ITO and Chuji HIROSE

Research Department, Pesticides Division, Sumitomo Chemical Co. Ltd., 4-2-1
Takatsukasa, Takarazuka, Hyogo 665, Japan

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Permethrin, fenvalerate, fenpropathrin, fenitrothion, lindane and chlordane were evaluated as a surface-applied wood protectant to control *Lyctus brunneus*, and the mode of protective action is discussed. The minimum effective concentrations of treatment liquid for wood protection were 40 ppm for fenpropathrin, fenvalerate and lindane, 200 ppm for permethrin and fenitrothion and 1000 ppm for chlordane. The treatment of fenpropathrin, fenvalerate and permethrin resulted in no oviposition of the female adults. On the other hand, the effect of chlordane might be due to death of hatched larvae. In the case of fenitrothion and lindane, dead larvae immediately after hatching were found in the wood treated at 200 ppm, but at 1000 ppm no larva was found. It seems that their protective action was dependent upon dosage.

INTRODUCTION

SMITH (1968) reported that the treatment of lindane emulsion at a concentration of 0.06% on wood surface prevented attacks of *Lyctus* powder-post beetle over 1 year. Similarly, ITO and HIROSE (unpublished data) observed that lindane of 0.1% or chlordane of 2.0% protected wood from *Lyctus brunneus* over 2 years. On the other hand, when these insecticides were directly applied on eggs, larvae and adults of *L. brunneus*, they showed low toxicities from which effectiveness in protecting wood from the beetle could not be expected (ITO and HIROSE, 1979a). Therefore, elucidation of mode of protective action of the insecticides against *L. brunneus* is necessary to further research for effective insecticides as a wood protectant.

In this paper, the effectiveness of lindane, chlordane, fenitrothion and pyrethroidal insecticides in protecting wood from *L. brunneus* and their mode of action on wood are examined.

MATERIALS AND METHODS

Insect. *Lyctus brunneus* successively reared on artificial diet (ITO and HIROSE, 1979b) was used throughout this work.

Insecticides. Fenitrothion (*O,O*-dimethyl *O*-(3-methyl-4-nitrophenyl) phosphorothioate, 95.6%), permethrin (3-phenoxybenzyl 2,2-dimethyl 3-(2,2-dichlorovinyl) cyclopropane-1-carboxylate, 92.4%), fenvalerate (α -cyano-3-phenoxybenzyl 2-(4-chloro-

phenyl) isovaralate, 93.2%), fenpropathrin (α -cyano-3-phenoxybenzyl 2,2,3,3-tetramethyl cyclopropane-1-carboxylate, 96.4%), chlordane (2,3,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene, technical grade) and lindane (1,2,3,4,5,6-hexachlorocyclohexane, 99.8%) were formulated as emulsifiable concentrates; each active ingredient 10%, the emulsifier (Sorpul® SM 100P, Toho Chem.) 20% and xylene, the balance.

Preparation of wood. Sapwood of tropical wood, red meranti, was cut to provide a wood block with cross-section of 1.5×1.5 cm and 1.5 cm length for protective test and a wood strip with cross-section of 5×2 cm and 45 cm length for penetration test, respectively. In the former test, wood containing starch of over 2.0% was used. The long axis of the strip was parallel to the grains of wood and its wide face was tangential to the growth rings. The end-grain of the block and strip was sealed with paint.

Protective test. The block of wood was dipped into a suspension of the insecticide at given concentrations for 30 sec, and thereafter dried at 25°C for 3 days. The treated block was placed in a petri dish (9 cm in diameter) with 3 pairs of male and female adults of *L. brunneus* and incubated at 25°C and 70% relative humidity. The mortality of the adults was observed after 24 hr. Median lethal concentration (LC_{50}) was calculated according to probit analysis. Four months after liberation of the adults, X-ray photograph of the block was taken to observe larvae which developed in it. The conditions to irradiate X-ray were as follows;

Apparatus; Soft X-ray equipment (Softex, Type CMBW)

Operation; Electric pressure of 40 KVp, electric current of 40 mA, irradiation period of 80 sec, irradiation distance of 45 cm.

Film; Softex film (Fuji, Type FG)

When no larva was found in the block by X-ray observation, the four faces except for cross-section of the block were shaved by 0.2 mm in thickness. Unhatched eggs and dead larvae, which were too small to observe by X-ray observation, on the inner surfaces of shavings and the newly formed surfaces of the block were examined under a microscope. The experiments were replicated three times.

Penetration of the insecticides into wood. The emulsifiable concentrates of fenitrothion, chlordane and permethrin were mixed at the ratio of 1/1/1 on a weight/weight basis, and diluted with water to give a concentration of 0.1% with respect to each active ingredient. An appropriate amount of methylene blue was added to the diluted emulsion. The wood strip was dipped into the emulsion for 5 min, and thereafter dried

Fig. 1. Method of cutting block to produce two small strips.

Fig. 2. Wood vessels dyed by methylene blue (arrow) at about 0.3 mm in depth from surface.

at 25°C for 3 days. As illustrated in Fig. 1, two 20 × 4 × 2 cm strips were made from the original strip and designated A and B strips. Each strip was shaved at every 0.3 mm to 1.5 mm depth from the surface.

Shavings from the B strip (about 0.5 g in weight) were extracted twice with 100 ml of acetone at 50°C for 2 hr. The combined extract was filtered through a filter paper and the filtrate was concentrated on a rotary evaporator. The concentrate was chromatographed on a silica gel thin layer (Merck F-254, 2 mm in thickness) using a solvent system of n-hexane/acetone (10/0.5, v/v). Silica gel at portions of R_f 0.1 to 0.3 and R_f 0.4 to 0.9, which respectively correspond to R_f values of fenitrothion, and chlordane and permethrin, was scraped from the plate and followed by elution with acetone. In the case of shavings from the A strip, only portions dyed by methylene blue as shown in Fig. 2 were scraped and collected. The insecticides from them were extracted, chromatographed and followed by elution as mentioned above. The A and B acetone extracts were concentrated to dryness on a rotary evaporator, and analyzed by gas-liquid chromatography. Determinations of the amount of fenitrothion and chlordane were carried out according to TAKIMOTO et al. (1976) and THRUSTON (1965), respectively. Permethrin was analyzed according to the analytical method of chlordane. As internal standards, ethyl parathion for fenitrothion, EPN for chlordane and 3-phenoxylbenzyl 2,4-dichlorobenzoate for permethrin were used.

When 0.5 ml of acetone solutions containing each insecticide at 10 and 1000 ppm was added to 0.5 g of shavings of wood, recoveries were about 90% in any case.

RESULTS

Table 1 shows mortalities of the adults of *L. brunneus* 24 hr after liberation. The LC₅₀ values of fenpropathrin, fenvalerate, fenitrothion, permethrin and lindane were 23, 79, 147, 247 and 744 ppm, respectively. Chlordane did not present any killing activity against the adults.

Protective effectiveness of the insecticide against attacks by *L. brunneus* in wood was examined by X-ray observation (Fig. 3). The results are represented in Table 2. At a concentration of 1000 ppm, all of the insecticides tested entirely protected the woods from *L. brunneus*. Fenvalerate, fenpropathrin and lindane were highly effective and the blocks treated with 40 ppm of each were free from injury. Lindane showed the most superior effectiveness. Chlordane was least effective. Even at 200 ppm, it could not protect one of 3 blocks and at the lower concentrations not at all.

Table 1. MORTALITIES OF THE ADULTS OF *L. brunneus* LIBERATED ONTO THE BLOCKS OF WOOD TREATED WITH THE INSECTICIDES

Insecticide	Percentage of Mortality after 24 hr				LC ₅₀ (ppm)
	1000	200	40	8 ppm	
Fenitrothion	88.9	61.1	22.2	0.0	144
Chlordane	0.0	0.0	0.0	5.6	—
Lindane	55.6	33.3	16.7	11.1	744
Permethrin	72.2	55.6	11.1	5.6	247
Fenvalerate	94.4	50.0	33.3	16.7	79
Fenpropathrin	94.4	83.3	66.7	27.8	23
Untreated	(5.6)

Fig. 3. X-ray photograph of fully developed larvae in wood.

Fig. 4. Dead larvae at the early developmental stage in the block of wood treated with chlordane at 1000 ppm (A: Dead larva, B: Egg shell).

Table 2. THE EFFECTS OF THE INSECTICIDES IN PROTECTING WOOD FROM ATTACKS BY *L. brunneus*. THE ADULTS WERE LIBERATED ONTO THE TREATED BLOCKS OF WOOD 3 DAYS AFTER TREATMENT

Insecticide	Number of Damaged Blocks ^a out of Three Blocks			
	1000	200	40	8 ppm
Fenitrothion	0	0	3	3
Chlordane	0	1	3	3
Lindane	0	0	0	1
Permethrin	0	0	1	2
Fenvalerate	0	0	0	2
Fenpropathrin	0	0	0	3
Untreated	(3)			

^a Number of blocks in which mature larvae were found by X-ray observation. X-ray photograph was taken 4 months after liberation of the adults.

Table 3. THE EFFECTS OF THE INSECTICIDES ON OVIPOSITION OF *L. brunneus*

Insecticide	Number of Blocks without oviposition/Three Blocks			
	1000	200	40	8 ppm
Fenitrothion	3	0	0	0
Chlordane	0	0	0	0
Lindane	3	1	2	0
Permethrin	3	3	1	0
Fenvalerate	3	3	3	1
Fenpropathrin	3	3	3	0
Untreated	(0)			

Since only mature larvae were detectable by X-ray observation, it was undistinguishable whether no mature larva in the blocks was due to no oviposition of the female adults, or death of young larvae which were undetectable. In order to ascertain it, the blocks in which no mature larva could be found by X-ray observation were shaved to examine for unhatched eggs and dead young larvae (Table 3). Dead larvae at the

Fig. 5. Penetration of fenitrothion, chlordane and permethrin into red meranti wood. The insecticides were extracted from whole shavings (B) and from the dyed portions on shavings (A).
● : permethrin, ▲ : chlordane, ○ : fenitrothion

early developmental stage could be observed in all blocks treated with chlordane at 1000 ppm. However, permethrin, fenpropathrin and fenvalerate did not allow the female adults to oviposit at the concentration of 40 ppm or above except for permethrin at 40 ppm. In the cases of treatment with lindane and fenitrothion, there was evidence of oviposition at a concentration of 200 ppm, but not at a concentration of 1000 ppm.

For the assessment of penetration of the insecticides under the same conditions, the wood strip was treated with a mixture of permethrin, chlordane and fenitrothion. The insecticides were extracted from whole shavings of wood or from only portions of wood dyed by methylene blue. Fig. 5 shows the results. The concentration of the insecticides tested decreased with depth from the surface in B, but it was constant regardless of depth from the surface in A. This meant that the insecticides deposited surrounding wood vessels, because methylene blue deposited surrounding the vessels as shown in Fig. 2. There was no significant difference in penetration degree among these insecticides in A and B.

DISCUSSION

ITO and HIROSE (1979a) reported low toxicity of chlordane against eggs, fully mature larvae and adults of *L. brunneus*, when directly applied. Table 1 also showed no toxicity of chlordane against the adults. However, the treatment of wood with chlordane at 1000 ppm was very effective for protection of wood from *L. brunneus* as shown in Table 2. As evidence of oviposition, dead larvae were found in the blocks treated with chlordane at 1000 ppm. This meant that the female adults could lay eggs in the treated blocks, and the larvae could hatch from eggs. Death of larvae at the early developmental stage (Fig. 4) was very interesting, because the insecticides deposited surrounding wood vessels, in which eggs were laid by the female adults.

It was thought that larvae had to contact chlordane immediately after hatching and died without boring through wood vessels. The protective effectiveness of chlordane obtained in this experiment depended on its toxicity against hatched larvae.

No evidence of oviposition was obtained in the blocks treated with pyrethroidal insecticides at the concentration of 40 ppm or above except for permethrin at 40 ppm. Moreover, there were 'few tasting marks' on the treated blocks with high concentrations of these insecticides. (It is well known that 'tasting mark' is made on wood by the female adults before their ovipositions (PARKIN, 1934; CYMOREK and SCHMIDT, 1976; ITO and HIROSE, 1978)). This observation suggests that pyrethroidal insecticides did not only permit the female adults to oviposit, but also to make 'tasting mark'. In fact, ITO and HIROSE, (1979a) reported rapid action of these insecticides against the adults of *L. brunneus*. Therefore, protective effectiveness of pyrethroidal insecticides obtained in this experiment would be ascribed to no oviposition of the female adults.

In the cases of fenitrothion and lindane, dead larvae at the early developmental stage were observed at the treatment of 200 ppm, but at 1000 ppm no larva was found. Thus, it seems that their protective effectiveness was dependent upon dosage.

There was no relationship between mortality of the adults after 24 hr of liberation and protective activity. For example, although mortalities of the adults at the treatment of fenitrothion and fenvalerate at 40 ppm were 22.2% and 33.3%, respectively, all three blocks treated with the former were damaged and no block treated with the latter was damaged. This phenomenon suggests that pyrethroidal insecticides affected oviposition of the female adults without killing. Therefore, further research concerning mode of protective action of pyrethroidal insecticides is necessary.

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