

Yann C, Bernard G, Patrick D (2012) Efficacy of methyl iodide, sulfuryl fluoride and cypermethrin against the six-toothed bark beetle: *Ips sexdentatus* (Börner). In: Navarro S, Banks HJ, Jayas DS, Bell CH, Noyes RT, Ferizli AG, Emekci M, Isikber AA, Alagusundaram K, [Eds.] Proc 9th. Int. Conf. on Controlled Atmosphere and Fumigation in Stored Products, Antalya, Turkey. 15 – 19 October 2012, ARBER Professional Congress Services, Turkey pp: 254-259

EFFICACY OF METHYL IODIDE, SULFURYL FLUORIDE AND CYPERMETHRIN AGAINST THE SIX-TOOTHED BARK BEETLE: *IPS SEXDENTATUS* (BÖRNER)

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ABSTRACT

Since the ban of methyl bromide for QPS uses in European Union, sulfuryl fluoride is the only fumigant registered in France for log disinfestation. Treatments must be done in fumigation chambers. This study was carried out to investigate the efficacy of two fumigants: sulfuryl fluoride and methyl iodide and a contact insecticide: cypermethrin under different conditions against all stages of the six-toothed bark beetle *Ips sexdentatus*. Ten infested pieces of pine (*Pinus pinaster*) were treated for each test series. Cypermethrin was sprayed on all surfaces of the logs with an application rate of 5 g of cypermethrin per cubic meter of wood. Sulfuryl fluoride fumigation was carried out in a 17 m³ chamber at 30 g m⁻³ and an exposure time of 24 hours. The methyl iodide fumigations were carried out in a 17 m³ chamber at 35 g m⁻³ and in a 20 feet container at 50 g m⁻³ and an exposure time of 24 hours. The efficacy of each insecticide was evaluated by comparing the emergence reduction of adult six-toothed bark beetles between control and treated logs. Ten weeks after treatment, the treated logs showed an emergence reduction of six-toothed bark beetle of 88.53% with cypermethrin, 99.92% with sulfuryl fluoride and a concentration time product (CTP) of 716 g h m⁻³ and 100% for methyl iodide fumigations with a CTP of 825 and 942 g h m⁻³ respectively in the fumigation chamber and container.

Key words: Six-toothed bark beetle, *Ips sexdentatus*, cypermethrin, sulfuryl fluoride, methyl iodide

INTRODUCTION

After the phase out of methyl bromide in European Union in 2010, including for QPS uses, methyl iodide was identified as a possible ozone-safe alternative to disinfest timber logs (Ohr et al., 1995). Fumigation is a crucial step to kill insects inside pine wood and to avoid introducing quarantine species into foreign countries. Methyl iodide seems to have the same action spectrum (insecticide, fungicide, nematicide...) as methyl bromide (Waggoner et al.,

2000; Ciesla et al., 2010; Muthu and Srinath, 1974). In France, the six-toothed bark beetle *Ips sexdentatus* (Börner) (Scolytinae, Curculionidae) is the main pest which infests pine wood (*Pinus sp.*). The aim of this trial is to compare the efficacy of two fumigants: methyl iodide (MI), not yet registered, sulfuryl fluoride (SF), and a contact insecticide: cypermethrin. For the moment, sulfuryl fluoride is registered in France for the fumigation of timber but with a restriction: the fumigation has to be done in a fumigation chamber, not in containers. This study was carried out, in Bordeaux, France, on infested pine logs and the efficacy of each insecticide was assessed by comparing the emergence reduction of insects between each treatment and control.

MATERIALS AND METHODS

Insecticides

Three insecticides were tested in this study:

- methyl iodide with a fumigation in a 17 m³ chamber at 35 g m⁻³ and a fumigation in a 20 feet container at 50 g m⁻³
- sulfuryl fluoride (Profume[®]) at 30 g m⁻³ in a 17 m³ fumigation chamber
- cypermethrin sprayed with an application rate of 5 g of cypermethrin per cubic metre of wood

Methyl iodide (Midas Technical) was supplied by Arysta LifeScience in 1 litre flasks. Methyl iodide is liquid at ambient temperature with a boiling point of 42.5°C. The fumigation was carried by introducing liquid methyl iodide on a stainless shallow pan next to a fan to mix the gas in the fumigated volume. In the 33 m³ container, 1650 grams of MI were introduced and 595 grams in the 17 m³ fumigation chamber. Methyl iodide concentrations were measured by thermoconductivity with a Fumiscope.

Sulfuryl fluoride (Profume[®]) was supplied by Dow AgroSciences in cylinders under pressure. The cylinder was connected with the fumigation chamber and the fumigation was carried out by introducing 510 g of sulfuryl fluoride into the chamber through a 2 mm stainless tube. The concentration of sulfuryl fluoride was measured with an infra-red analyser (Spectros IR).

Cypermethrin (Forester EW) is a pyrethroid and was supplied by Agriphar. The formulation (100 g active, per litre) was applied as a 1% mixture. The treatment of wood needs 1 g of cypermethrin per litre of mixture in order to spray the surfaces of the logs, equivalent to 5 L of mixture per m³ of wood. The 10 pine logs represent about 0.3 m³, so 1.5 L of mixture was applied.

The temperature and relative humidity were recorded for the fumigation and the insecticide treatment with Captsystems[®] loggers.

Wood

The treated pine logs (*Pinus pinaster*) were 1m in length with diameters ranging from 9 to 19.5 cm. A total of 50 logs were used, with 10 pieces of wood in each test series. The selection of the pine logs was made at random. The infestation of six-toothed bark beetles was natural, so infestation varied between logs. The pine logs came from pine trees cut at the beginning of 2011. Each piece of wood was identified with a number (Table 1).

When the six-toothed bark beetle reaches the adult stage, it emerges from the bark and come out the log. Emerging insects are trapped in a cage composed of an insect-proof net. They are attracted by sunlight, then move to the funnel and fall into the insect box (Fig). Every day, the 50 boxes were collected in order to count the emerged insects in test series. These boxes were collected for 10 weeks in 2011. This study began on 27 June (week 26) and was finished on 5 September (week 35).

Table 1. Identifying numbers of each pine log for each test series

Control									
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Cypermethrin									
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Sulfuryl fluoride									
SF1	SF2	SF3	SF4	SF5	SF6	SF7	SF8	SF9	SF10
Methyl iodide in fumigation chamber									
MICH1	MICH2	MICH3	MICH4	MICH5	MICH6	MICH7	MICH8	MICH9	MICH10
Methyl iodide in container									
MICO1	MICO2	MICO3	MICO4	MICO5	MICO6	MICO7	MICO8	MICO9	MICO10

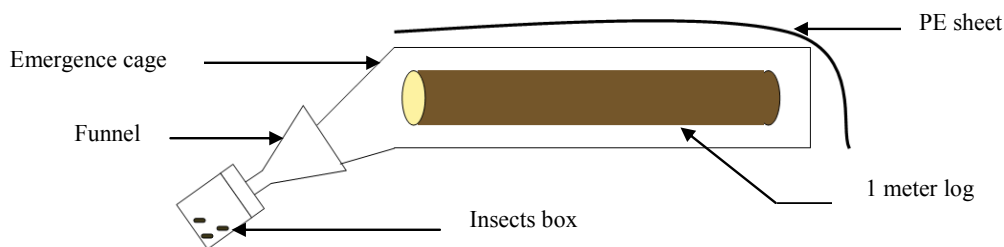


Fig. 1- Composition of an emergence cage.

Insects

The six-toothed bark beetle *Ips sexdentatus* is the largest bark beetle in France, measuring up to 8 mm in length. Generally there are two adult flights per year, one in April-May and the second in July-August, these flights depending of the climatic conditions. The pine logs were naturally infested during the 2011 spring. The efficacy of each treatment was assessed by comparing the reduction of emergence of six-toothed bark beetles with the control. In the case of cypermethrin treatment, the death of insects is not instantaneous, so it is necessary to discriminate between insects which emerge and die after few hours and insects which can survive several days after emergence. An adult insect was considered as alive if it can move and reach the insect box. An adult insect was considered as dead if it died in the emergence cage without ever reaching the lighted part of net and subsequently the insect box.

RESULTS AND DISCUSSION

The measured concentrations show that there was no leakage from the fumigation chamber and the sorption is insignificant. The concentration of sulfuryl fluoride (30 g m^{-3}) and methyl iodide (35 g m^{-3}) at the beginning of the fumigation was the same as 24 hours later (Fig. 2). The actual CT product was practically the theoretical CT product, with 716 and 825 g h m^{-3} respectively for sulfuryl fluoride fumigation (Fig. 2- Evolution of concentrations of sulfuryl fluoride (points), methyl iodide in the 17 m^3 chamber (triangles) and methyl iodide in the container (rhombs) during the fumigation of 10 pine logs respectively at 30 g/m^3 , 35 g/m^3 and 50 g/m^3 . Table) and the methyl iodide fumigation in chamber (Table). The container was not as well sealed, with the theoretical concentration at 50 g m^{-3} but, after 24 hours, only 35 g m^{-3} methyl iodide remained. The CT product achieved for this fumigation in the container was 942 g h m^{-3} (Table).

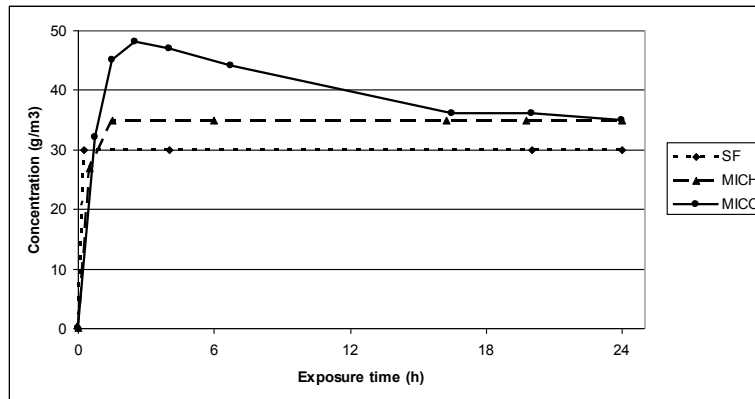


Fig. 2- Evolution of concentrations of sulfuryl fluoride (points), methyl iodide in the 17 m³ chamber (triangles) and methyl iodide in the container (rhombs) during the fumigation of 10 pine logs respectively at 30 g/m³, 35 g/m³ and 50 g/m³.

Table 2. Concentrations of sulfuryl fluoride measured and calculated concentration-time products after a fumigation of 10 pine logs at 30 g m⁻³ in a 17 m³ chamber

Exposure time (h)	Concentration (g m ⁻³)	CT product (g h m ⁻³)
0	0	0
0.25	30	4
4	30	116
20	30	596
24	30	716

Table 3. Concentrations of methyl iodide measured and calculated concentration-time product after a fumigation of 10 pine logs at 35 g m⁻³ in a 17 m³ chamber

Exposure time (h)	Concentration (g m ⁻³)	CT product (g h m ⁻³)
0	0	0
0.5	27	7
1.5	35	38
6	35	195
16.25	35	554
19.75	35	676
24	35	825

Table 4. Concentrations of methyl iodide measured and calculated concentration-time product after a fumigation of 10 pine logs in a container at 50 g m⁻³

Exposure time (h)	Concentration (g m ⁻³)	CT product (g h m ⁻³)
0	0	0
0.75	32	12
1.5	45	41
2.5	48	87
4	47	159
6.75	44	284
16.5	36	674
20	36	800
24	35	942

For these treatments, the temperature was recorded and the data show that the spraying of cypermethrin was applied at 34.8°C in average (Table 5). In average the temperatures recorded for fumigations (MI and SF) carried out in the chamber were about 24°C. The fumigation with MI in the container was carried at 20.4°C in average.

Table 5. Temperature and relative humidity recorded for each treatment

Test series	Temperature (°C)	Relative humidity (%)
Cypermethrin	34.8	34
Sulfuryl fluoride	24.2	78
Methyl iodide in chamber	23.6	69
Methyl iodide in container	20.4	70

Table 6. Total of emerged adult six-toothed bark beetles collected in the insect boxes per week (W) and percentage of emergence reduction after ten weeks in the test series: T = control; F = cypermethrin; SF = sulfuryl fluoride; MICH = methyl iodide in chamber; MICO = methyl iodide in container

Total emerged adult six-toothed bark beetles/week/test										Total 10 weeks	Emergence reduction (%)
W26	W27	W28	W29	W30	W31	W32	W33	W34	W35		
T	T	T	T	T	T	T	T	T	T	T	T
244	59	52	21	406	216	167	80	29	34	1308	-
F	F	F	F	F	F	F	F	F	F	F	F
9	21	30	19	33	19	13	4	2	0	150	88.53
SF	SF	SF	SF	SF	SF	SF	SF	SF	SF	SF	SF
0	0	0	0	0	0	0	0	1	0	1	99.92
MICH	MICH	MICH	MICH	MICH	MICH	MICH	MICH	MICH	MICH	MICH	MICH
0	0	0	0	0	0	0	0	0	0	0	100
MICO	MICO	MICO	MICO	MICO	MICO	MICO	MICO	MICO	MICO	MICO	MICO
0	0	0	0	0	0	0	0	0	0	0	100

Ten weeks after treatment, 1308 adult six-toothed bark beetles emerged from the 10 pine logs in the control, 150 from the pine logs treated with cypermethrin, just one from sulfuryl fluoride modality, in the pine log SF8, and none from the 10 pine logs fumigated with methyl iodide in chamber or methyl iodide in container (Table 6). The emergence reduction was 100 % between the control and the methyl iodide tests. The percentage of emergence reduction in the sulfuryl fluoride test was 99.92 % and 88.53 % with cypermethrin. In the emergence cages corresponding to pine logs treated with cypermethrin, a lot of insects emerged and died in these cages without being able to reach the insect boxes. The infestation varied with each pine log. The average number of emerged adult insects per pine log after 10 weeks in the control was about 131 ± 86.5 , with 309 insects in the most infested pine log (T8) and 23 insects in the least infested pine log (T2).

CONCLUSION

The aim of the study was to investigate the efficacy of cypermethrin treatment, methyl iodide and sulfuryl fluoride fumigations against the six-toothed bark beetle in order to disinfect pine logs. Ten weeks after treatment, methyl iodide fumigations with a CTP of 825 g h m⁻³ at 23.6°C and a CTP of 942 g h m⁻³ at 20.4°C were effective, killing all stages of this insect. A fumigation with sulfuryl fluoride at 24.2°C and a CTP of 716 g h m⁻³ was almost sufficient to kill all stages of this insect. Actually the percentage of emergence reduction was 99.92 % and just one adult emerged from the 10 treated pine logs after 10 weeks compared with the 1308 adults insects emerged in the control. The surviving adult insect emerged nine weeks after treatment, so it is possible that it was an egg when the pine logs were fumigated. A fumigation with a higher temperature or a higher CTP could improve this efficacy and give an emergence reduction of 100 %. Cypermethrin treatment, with a spraying on all the faces of pine logs, shows an emergence reduction of 88.53 % compared with control. This result could be improved with an higher application rate, but for quarantine pest control it will be very difficult to reach an efficacy to reach the desire probit 9 level. Moreover the spraying needs to apply the insecticide on all the faces of pine wood to ensure a better efficacy, this is difficult to carry out well in the field on pine logs or timbers. Methyl iodide and sulfuryl fluoride are fumigants with the potential to replace methyl bromide to control six-toothed bark beetles.

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