THE ACTIVITY OF THE FUMIGANT SULFURYL FLUORIDE ON STORED PRODUCT INSECT PESTS

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Abstract—Sulfuryl fluoride is a gas fumigant mainly used for the control of structural and household insect pests. A laboratory study was undertaken to determine the efficacy of the fumigant on eight stored product pest insects (*Sitophilus granarius, Oryzaephilus surinamensis, Tribolium confusum, Stegobium paniceum, Trogoderma inclusum, Tenebrio molitor, Plodia interpunctella, Ephestia kuehniella).* Several concentrations ranging from 11.7 ± 0.4g/m^3 to 35 ± 0.2g/m^3 were evaluated in the study. The temperature was maintained at 20° C and insect eggs, larvae and adults exposed for periods of 24, 48 or 72h. Mortality of adults, larvae and hatching of eggs was assessed. Larvae, pupae and adults were the most susceptible to sulfuryl fluoride whilst eggs were the most tolerant. All stages of tested insects were killed by 35 ± 0.2g/m^3 of the fumigant within a 24h exposure time at 20°C. Further laboratory studies are being undertaken to confirm these preliminary results prior to field evaluation.

INTRODUCTION

The characteristics and global potential of the fumigant gas sulfuryl fluoride (SO_2F_2) was reviewed by Schneider (1993). The fumigant is mainly used for the control of structural and household insect pests. It may also have potential for other areas where fumigation is needed for pest control apart from soil, grain and food commodities.

Sulfuryl fluoride is an inorganic chemical which is non-flammable, non-corrosive and is without odour or colour. It has low water solubility (750 ppm at 25°C), a high vapour pressure (13,442mm Hg at 25°C) and a boiling point of −55.4°C. The critical route of exposure is through inhalation and the Threshold Limit Value is 5ppm. The fumigant is chemically inert and its uses include eradication of damaging insect infestations in sensitive, high value areas e.g. historical churches, rare book libraries and museums.

Sulfuryl fluoride, following aeration of treated structures, quickly diffuses to the outside air where it rapidly dissipates to non-detectable levels. The fumigant is fully oxidised and does not interact with ozone (Bailey, 1992).

Professional fumigators are supplied with the product Vikane* which contains 99% sulfuryl fluoride and 1% inert ingredients packed in cylinders as a liquid under pressure. The primary use of sulfuryl fluoride is as a structural fumigant for the control of drywood termites. Increasingly it is being adopted for the control of damaging wood infesting beetles and household insect pests. It is currently registered for use in the USA, Germany and Sweden. In Germany the main use is for the control of wood boring insects mainly *Anobium punctatum* and *Ptilinus pectinicornis.* These species pose a threat to the wooden interior of churches (Binker, 1993).

Research is currently being undertaken to evaluate the efficacy of sulfuryl fluoride on beetles infesting imported timber and on stored product insect pests in empty food processing and storage structures. This paper reports on a preliminary laboratory study, to determine the fumigant's activity on eight stored product insect pests.

MATERIALS AND METHODS

Eight stored product insect species from laboratory cultures maintained at the Institute for Stored Product Protection, Federal Biological Research Centre for Agriculture and Forestry, Berlin,

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Table 1. Efficacy of sulfuryl fluoride following fumigation for 24, 48, 72h at 20°C

Exposure Period	Insect Species	Insect Stage	Concentration of sulfuryl fluoride g/m3 11.7±0.4	13.3±0.2	18.2±0.4	18.6±0.5	23.5±0.3	26.5±0.3	35.0±0.2
24 h	1	E	–	▲	–	▲	–	▲	■
		L	–	■	–	■	–	■	–
		P	–	■	–	■	–	■	–
		A	–	■	–	■	–	■	–
	2	AS	–	■	–	▲	–	■	–
	3	AS	–	■	–	■	–	■	–
	4	AS	○	–	■	–	■	–	–
	5	AS	○	–	■	–	■	–	–
	6	L	■	–	■	–	■	–	–
		P	■	–	■	–	■	–	–
		A	■	–	■	–	■	–	–
	7	E,L,P	▲	–	▲	–	▲	–	–
	8	E,L,P	■	–	▲	–	■	–	–
48 h	1	E	–	▲	–	▲	–	▲	■
		L	–	■	–	■	–	■	■
		P	–	■	–	■	–	■	■
		A	–	■	–	■	–	■	■
	2	AS	–	■	–	▲	–	■	–
	3	AS	–	■	–	■	–	■	–
	4	AS	○	–	■	–	■	–	–
	5	AS	■	–	■	–	■	–	–
	6	L	■	–	■	–	■	–	–
		P	■	–	■	–	■	–	–
		A	■	–	■	–	■	–	–
	7	E,L,P	▲	–	▲	–	▲	–	■
	8	E,L,P	■	–	■	–	■	–	■
72 h	1	E	–	▲	–	■	–	■	■
		L	–	■	–	■	–	■	■
		P	–	■	–	■	–	■	■
		A	–	■	–	■	–	■	■
	2	AS	–	■	–	■	–	■	–
	3	AS	–	■	–	▲	–	■	–
	4	AS	○	–	■	–	■	–	–
	5	AS	○	–	■	–	■	–	–
	6	L	■	–	■	–	■	–	–
		P	■	–	■	–	■	–	–
		A	■	–	■	–	■	–	–
	7	E,L,P	■	–	■	–	▲	–	■
	8	E,L,P	■	–	■	–	■	–	■

Key:

1. *Sitophilius granarius*
2. *Oryzaephilus surinamensis*
3. *Tribolium confusum*
4. *Stegobium paniceum*
5. *Trogoderma inclusum*
6. *Tenebrio molitor*
7. *Ephestia keuhniella*
8. *Plodia interpunctella*

E Egg
L Larva
P Pupa
A Adult
AS All stages

■ 100% mortality
○ Surviving insects , no progency produced
▲ Surviving insects, progency produced
– No experiment

Germany were included in the study. These were Sitophilus granarius, *Oryzaephilus surinamensis, Tribolium confusum, Stegobium paniceum, Trogoderma inclusum, Tenebrio molitor, Plodia interpunctella* and *Ephestia kuehniella*. Samples of each test insect species were taken from the cultures, for S. granarius, a 2g grain sample was taken which contained all developmental insect stages. In the untreated sample thirty adult weevils subsequently developed. For all other insects, breeding stages were introduced, which led to the emergence of thirty or more adults in the untreated samples. Insects were exposed to concentrations of sulfuryl fluoride ranging from 11.7±0.4 g/m^3 to 35±0.2 g/m^3 at 24, 48 and 72h at 20° in a 0.5m^3 steel chamber as described by Reichmuth (1981). The concentration of the fumigant was determined by use of an infrared absorption spectrophotometer (Miran). Following exposure the insects were aerated for 3h and transferred with more standard substrate and maintained at 20°C and 65% r.h. The efficacy of the sulfuryl fluoride on egg, larva, pupa and adult and the ability of adults to produce progency was determined by counting dead, surviving and emerging adults 10–12 wk after fumigation.

RESULTS

At the lower concentrations of sulfuryl fluoride (11.7 ± 0.4–13.3 ± 0.2 g/m^3) and shortest exposure period (24h) 100% mortality of larva, pupa and adult stages was achieved for *S. granarius, T. confusum* and *T. molitor.* Some individuals of *S. paniceum* and *T. inclusum* continued development to the adult stage but no reproduction occurred. Higher concentrations for this exposure period were required for 100% mortality of eggs, larvae and pupae of *P. interpunctella* (23.5 ± 0.3 g/m^3), all stages of *O. surinamensis* (26.5 ± 0.3 g/m^3), and eggs of *S. granarius* (35.0 ± 0.2 g/m^3). Eggs of *E. kuehniella* survived following 24h exposure at 23.5 ± 0.3 g/m^3 which was the highest concentration tested.

When exposed for the longer period of 48h 100% mortality was achieved for all stages of *T. inclusum* at the lowest concentration (11.7 ± 0.4 g/m^3) evaluated. When exposed to the highest concentration (35.0 ± 0.2 g/m^2) for 72h egg stages of both *S. granarius* and *E. kuehniella* were killed (Table 1).

DISCUSSION

Insect pests are controlled by sulfuryl fluoride through disruption of the glycolysis cycle leading to deprivation of metabolic energy (Meikle, 1963). Its activity is dependent on the concentration reaching the target insect pest and duration of exposure. For structural insect pests the effective rate is usually between 20–30 g/m^3 for 48 to 72h. The results from this preliminary laboratory evaluation of the fumigant's activity suggest that total control of all stages of the tested insects can be achieved by use of 35 ± 0.2g/m^3 within 24h exposure at 20°C.

In this study the larvae, pupae and adults were the most susceptible stages to sulfuryl fluoride. The lowest concentrations tested (11.7 ± 0.4–13.3 ± 0.2 g/m^3) for 24h achieved 100% mortality of *S. granarius,T. confusum* and *T. molitor.* The egg insect stage appeared to be the most tolerant to the fumigant. The dose of 35.0 ± 0.2 g/m^3 in 24h of exposure was required to achieve complete kill of *S. granarius* and *E. kuehniella* eggs. The egg stage being most tolerant to sulfuryl fluoride has been reported for the stored product insect pest *T. molitor* (Outram, 1967 a,b) and various material destroying and household pests (Kenaga, 1957; LaFage *et al*, 1983; Schneider, 1993).

Further laboratory studies on sulfuryl fluoride are required to validate the results of this preliminary investigation. Providing efficacy results are confirmed the performance of the fumigant under practical field conditions will then be determined.

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