USE OF SULFURYL FLUORIDE AS AN ALTERNATIVE FUMIGANT TO METHYL BROMIDE IN EXPORT LOG FUMIGATION

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ABSTRACT

As the deadline for phasing out the use of methyl bromide as a fumigant approaches, alternative fumigants are being evaluated. Sulfuryl fluoride has emerged as a promising alternative and is gaining increasing acceptance in Europe. This study showed that sulfuryl fluoride was an effective fumigant for the control of *Arhopalus tristis* adults at the lowest concentration tested (15 g/m^3), while 120 g/m^3 was required for full control of *A. tristis* eggs. Sulfuryl fluoride also gave total control of *Hylastes ater* adults and larvae at 15 g/m^3. Sulfuryl fluoride showed potential to control the eight fungi tested in this study, with a concentration level of at least 30 g/m^3 required for full control of the eight fungi tested.

Keywords: fumigation, sulfuryl fluoride, export logs, methyl bromide alternative.

INTRODUCTION

Methyl bromide is still widely used to treat export forest products around the world despite its accepted role in depleting the ozone layer. Its use is still permitted for quarantine and pre-shipment purposes. Methyl bromide is also a controversial fumigant in New Zealand because of concerns over the alleged link between its use and the incidence of motor neurone disease in Nelson (Kiddle 2005).

Alternatives to methyl bromide are sought for forest product fumigation, so efforts have been made in New Zealand over the past few years to find an alternative. Phosphine has been suggested as one alternative (Zhang et al. 2004), but this fumigant is not known to have fungicidal potential and may not be effective against fungal growth during storage and shipping.

Another alternative fumigant is sulfuryl fluoride, an inorganic compound. It is an odourless, colourless non-flammable gas with the chemical formula SO_2F_2, a molecular weight of 102.10, a melting point of -137°C, and a vapour pressure of 1.7 mPa at 21°C. Sulfuryl fluoride is soluble in water at 750 mg/litre at 25°C, and is soluble in ethanol, toluene and carbon tetrachloride. Sulfuryl fluoride is non-reactive and non-corrosive at temperatures normally encountered in structural and other fumigations (EPA 2003). Recent studies found that sulfuryl fluoride was effective against fruit insects (Bell et al. 1999) and was able to control fungi that cause graystain on wood (Schmidt et al. 2001).

This study evaluated the efficacy of sulfuryl fluoride for control of two major New Zealand forest insect pests at different life stages. *Hylastes ater* (Paykull) (Coleoptera: Scolytidae) and *Arhopalus tristis* (Mulsant) (Coleoptera: Cerambycidae) are of quarantine importance to overseas authorities such as the Australia Quarantine and Inspection Services and the Chinese Authority of Quality Supervision and Inspection and Quarantine. Sulfuryl fluoride was also tested against representative fungi commonly found in New Zealand that might be present on exported timber.

MATERIALS AND METHODS

Insects

Sulfuryl fluoride efficacy was tested on two life stages of *A. tristis* (adults and eggs) and *H. ater* (adults and larvae). *Arhopalus ferus* adults and eggs were supplied by Dr Gordon Hosking of Frontline Biosecurity in Rotorua and were used in experiments as soon as they were couriered to Crop & Food Research in Palmerston North. *Hylastes ater* adults and larvae were collected from old stacks of pine logs at the Genesis Trust in Palmerston North, following removal of bark from logs. Sawdust left from the use of a chainsaw, and sweepings, were later sieved through a 4 mm sieve and used as a medium during the fumigation for holding insects. Adults and nymphs survive for at least 3 weeks at 15ºC on sawdust and a damp paper towel.

The sulfuryl fluoride used in this study was cylinderised sulfuryl fluoride supplied by Primaxa Ltd, Auckland. The sulfuryl fluoride concentration was measured, calibrated, and monitored using a Fumiscope (DowElanco) provided by Genera Ltd. Sulfuryl fluoride treatments were carried out for 24 h in 220 litre chambers in a temperature-controlled room of 15°C. This treatment duration and temperature were chosen to match conditions used for methyl bromide fumigation on forest products. Sulfuryl fluoride was assessed at five concentrations: 0, 15, 30, 60 and 120 g/m^3.

For *A. tristis*, there were four replicates of each treatment, with 20 adults and at least 50 eggs in each replicate. For *H. ater* there were 20 adults and 10 larvae in each replicate and there were four replicates of each treatment.

For fumigation, insects and larvae were held in a 70 ml plastic container. The lid had a mesh-covered hole for air and fumigant access. Sawdust (8–11 g) was placed in the container and an 8 cm^2 moist piece of paper towel was used to maintain high humidity and for food. Mortality assessments were made 2 days after treatment. For accurate assessment, *H. ater* and *A. tristis* adults were kept for 5 to 10 min in a shallow container to check for movement. Adults can appear dead and may only start walking after approximately 5 min.

Insect mortality data were analysed using logistic regression (Genstat, VSN International Ltd, UK, 2005), and confidence intervals for mortality rates calculated. Where mortality was 100%, confidence intervals were calculated using exact binomial proportions.

Fungi

The following fungal strains were selected for this study (NZFS Collection Number in brackets): *Cladosporium herbarum* (89), *Phlebiopsis gigantean* (1986), *Schizophyllum commun* (1014), *Armillaria novae-zelandiae* (1026), *Botryodiplodia theobromae* (1013), *Ophiostoma novo-ulmi* (572), *Phytophthora cinnamom* (657) and *Sphaeropsis sapinea* (15.26). The strains were prepared by Judy Gardener of Scion Research, Rotorua.

The fungi were all grown on 2% Malt Extract Agar (MEA) in Petri dishes in the dark at 23ºC for 3 days prior to exposure to the fumigant. Fumigation treatment used the same method as with the insects, with five concentrations of sulfuryl fluoride: 0, 15, 30, 60 and 120 g/m^3. There were five replicates of each treatment, one Petri dish per replicate. The fungal cultures were fumigated with the lids kept on to reduce possible airborne contamination, such as fungal spores.

After treatment, the fungal cultures in the Petri dishes were aerated under a fume hood for about 10 min. Two 5 mm plugs from each culture were then placed on fresh 2% MEA in a Petri dish and incubated in the dark at 23ºC for 14 days. The subcultures of the treated fungi were assessed for growth and contamination, and the results were recorded 7 and 14 days after subculturing. If colonies that grew from the subcultures showed characteristic colony morphology (matching the formal description of the fungus), they were judged as unaffected by the treatment (“normal” growth). Subcultures that did not grow or those that did not match the characteristic colony morphology description were judged as affected by the treatment (and not classed as “normal” growth).

RESULTS

Sulfuryl fluoride gave 100% control of adult *A. tristis* and near 100% mortality of *A. tristis* eggs (Table 1).

TABLE 1: Mean mortality of *Arhopalus tristis* adults and eggs after 24 h of sulfuryl fluoride fumigation.

	Adults		Eggs	
Concentration g/m^3	Mortality (%)	95% confidence interval	Mortality (%)	95% confidence interval
0	21.7	8.7-44.5	24.5	19.7-30.2
15	100	95.5-100	99.3	96.7-99.8
30	100	95.7-100	99.6	96.7-99.9
60	100	95.8-100	98.9	96.2-99.7
120	100	95.7-100	100	99.0-100

Sulfuryl fluoride was also effective for control of *H. ater* adults and larvae (Table 2).

TABLE 2: Mortality of *Hylastes ater* adults and larvae after 24 h of sulfuryl fluoride fumigation.

	Adults		Larvae	
Concentration g/m^3	Mortality (%)	95% confidence interval	Mortality (%)	95% confidence interval
0	7.5	3.4-15.9	10.0	3.7-24.2
15	100	96.3-100	100	92.8-100
30	100	95.7-100	100	92.8-100
60	100	95.8-100	100	92.8-100
120	100	95.7-100	100	92.8-100

Sulfuryl fluoride affected fungal growth at all rates used (Table 3).

TABLE 3: Number of plates showing normal fungal growth (out of a total of five plates) after treatment without or with four concentrations of sulfuryl fluoride.

	Sulfuryl fluoride (g/m^3)				
Fungi	0	15	30	60	120
C. herbarum	5	0	0	0	0
P. gigantean	5	1	0	0	0
S. commune	5	0	0	0	0
A. novae-zelandiae	5	1	0	0	0
B. theobromae	5	1	0	0	0
O. novo-ulmi	5	0	0	0	0
P. cinnamom	5	1	0	0	0
S. sapinea	5	1	0	0	0

DISCUSSION

This study has shown that sulfuryl fluoride was an effective fumigant for the control of selected life stages of *A. tristis* and *H. ater*, with a sulfuryl fluoride concentration of 15 g/m^3 being sufficient to achieve 100% mortality of adults and larvae. Sulfuryl fluoride is generally thought not to be very effective against insect eggs (Aung et al. 2001), although these trials showed 99% mortality at 15 g/m^3, which is a relatively low concentration. This may be due to the fact that the direct exposure treatment in this study was not affected by fumigant depletion through sorption from materials such as wood.

Sulfuryl fluoride has also shown potential for control of the eight fungi tested, with a required sulfuryl fluoride concentration level of at least 30 g/m^3.

Recent studies (Schmidt et al. 2001; Bell et al. 1999) have examined the efficacy of sulfuryl fluoride for control of fruit insects and fungi that induce graystain on wood, and have provided useful information for setting up sulfuryl fluoride fumigation protocols for export forest products. The present study gave promising results on control of New Zealand forest insects and fungi that are quarantined by overseas authorities (Zhang et al. 2004), suggesting it may be possible to substitute sulfuryl fluoride for methyl bromide for forest product fumigation in New Zealand.

The research presented in this paper used a direct exposure treatment method. No logs or timber were involved so further verification is required with insects and fungi *in situ*. Sulfuryl fluoride sorption by timber and penetration into wood needs to be understood before developing a successful fumigation protocol using sulfuryl fluoride. Sulfuryl fluoride is known to have better timber penetration qualities than methyl bromide (Scheffrahn et al. 1987).

Sulfuryl fluoride has potential as a wide-spectrum fumigant for both insect and fungus control. Further work is necessary before commercial use. This should include scaling up sulfuryl fluoride treatment on fungi and wood, assessment of the ability of sulfuryl fluoride to penetrate and control bark-borne insects and fungal spores and determination of the necessary post-treatment aeration period required for safe fumigation operation.

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REFERENCES

Aung LH, Leesch JG, Jenner JF, Grafton-Cardwell EE 2001. Effects of carbonyl sulfide, methyl iodide, and sulfuryl fluoride on fruit phytotoxicity and insect mortality. Annals of Applied Biology 139(1): 93–100.

Bell CH, Savvidou N 1999. The toxicity of Vikane (sulfuryl fluoride) to age groups of eggs of Mediterranean flour moth (*Ephestia kuehniella*). Journal of Stored Products Research 35(3): 233-247.

EPA 2003. Structural fumigation using sulfuryl fluoride: DowElanco's Vikane™ gas fumigant. http://www.epa.gov/spdpublc/mbr/casestudies/volume2/sulfury2.html (accessed 28 April 2006).

Kiddle E 2005. Cluster Investigation into Motor Neurone Disease. www.mndanz.org.nz/attachments/FinalDraft_Cluster_investigation_may_05.pdf (accessed 28 April 2006).

Scheffrahn R, Osbrink W, Hsu R, Su NY 1987. Desorption of residual sulfuryl fluoride from structural and household commodities by headspace analysis using gas chromatography. Bulletin of Environmental Contamination and Toxicology 39: 769–775.

Schmidt EL, Cassens DL, Jordan BA 2001. Control of graystain in yellow-poplar lumber by log fumigation with sulfuryl fluoride. Forest Product Journal 51(9): 50-52.

Zhang Z, van Epenhuijsen CW, Brash DW, Hosking GP 2004. Phosphine as fumigant to control *Hylastes ater* and *Arpopalus ferus*, pests of export logs. New Zealand Plant Protection 57: 257–260.