Efficacy of three fumigant methods for empty ship holds against stored product insect adults and eggs.

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Why Investigate Alternatives to Methyl Bromide for Ship-hold Fumigations?

Methyl bromide has been identified as an ozone depleting substance and the developed countries signatory to the Montreal Protocol must phase-out its use by the year 2005. The Montreal Protocol presently exempts the use of methyl bromide for quarantine and pre-shipment purposes. This exemption, however, was one of the main topics of discussion at the Meeting of the Parties in Cairo in 1998, and again at the Open Ended Working Group meeting in Geneva. The definitions for quarantine and pre-shipment are unclear, and there is apparent abuse of this exemption. In particular, the pre-shipment exemption is the most contentious.

Members of the Canadian Industry/Government Working Group on Methyl Bromide Alternatives believe that an investigation into alternatives for ship hold applications would demonstrate the effectiveness of potential alternatives that are either currently registered or not registered for use in Canada, and their associated costs. Furthermore, these techniques may be useful in other situations where methyl bromide is used to control insect infestations.

Methods

The test was conducted on lake-going ship, the “Canadian Trader”, that has six holds, 5000 to 7000 m^3 each. There were four treatments: methyl bromide at approximately 16,000 ppm (21 oz/1000 ft^3) with recapture after one day (hold 1), phosphine at 500 ppm applied using the Eco_2Fume ™ method (hold 4), phosphine at 1000 ppm applied using the Horn generator using magnesium phosphide (hold 6), and an untreated control (hold 3). To recapture the methyl bromide the air from the ship hold was passed over a molecular sieve, a technique developed by Cryo-Line Supplies Inc. Eco_2Fume ™ is 2 % phosphine with 98% carbon dioxide in pressurized cylinders, and is produced by Cytec Canada Inc. The Horn generator produces phosphine by mixing magnesium phosphide powder with water, and is produced by Degesch America Inc.

Four insects were used in the bioassay: rusty grain beetle (*Cryptolestes ferrugineus* (Stephens)), rice weevil (*Sitophilus oryzae* (L.)), red flour beetle (*Tribolium castaneum* (Herbst)), and the lesser grain borer (*Rhyzopertha dominica* (Fabricus)). Twenty-five mixed-aged adults were placed in plastic vials with screen tops containing 10 g of wheat with 20% cracked grain on Wednesday, June 2, held at 30EC for 24 h, transported from Winnipeg to Toronto (approximate temperature 20EC) and placed in the ship holds on Saturday, June 5. This allowed females to lay eggs, but eggs would not have hatched before the fumigation. Hence all vials contained both eggs and adults in the same vial.

Vials were taped to a rope with one set (four species, four replicates/species) at the bottom of the hold (12 m from top), one set midway (6 m from top), one set at the top of the hold. Three ropes were hung from the manhole access to the hold, and one rope was pulled from each hold 32, 48 and 72 h after the beginning of the fumigation. For the methyl bromide treatment there was only one rope, and it was pulled at the completion of the methyl bromide fumigation, 32 h after the beginning of the fumigation. Temperatures were measured using thermocouple wires taped to the ship hold and the vials in each of the holds at the bottom, middle and top levels.

After removing a rope from a hold, adults were sieved out of the wheat from each vial, survival rate noted and the adults placed on clean wheat. After one week the number of live and dead adults was assessed a second time to detect delayed mortality or revival of insects that could have been counted as dead but were in a fumigant-induced stupor**.** To assess the survival of the eggs, the wheat that was held in the ship holds was placed at 30EC for five weeks and the number of emerged adults counted.

Results

Temperatures in the ship holds varied between a high of 33 EC to a low of 15EC during the three days of the test, with an average temperature during the first day of fumigation of 23EC. The target gas concentrations were reached at all three levels after 9 h for methyl bromide, 1 h for Eco^{2}Fume™ 500 ppm phosphine application and 7 h for Horn generator at 1000 ppm phosphine. Some phosphine was detected in the untreated hold at the bottom level, but it was never greater than 11 ppm.

After 32 h, none of the adult insects survived in any of the three fumigation treatments. In the untreated hold there was not more than 2% adult mortality for any of the species. After one week, none of the insects in the fumigated holds had revived, and the mortality in the untreated hold was not more than 5% for all species, except lesser grain borer which had an average mortality of 31±8% (mean±SEM). The emergence of adults from infested grain in the untreated hold varied between insects (Table 1). Given the low emergence for rusty grain beetles from the untreated samples, it was impossible to estimate the mortality due to fumigation. For the other insects, there was less than 7% survival of eggs after 32 h in the fumigated holds and less than, 1% survival after 48 h and no survival after 72 h (Table 1).

Discussion

All three of the methods tested in this trial have potential for reducing methyl bromide emissions resulting from empty ship fumigations. These methods could be scaled up for treating entire ocean going vessels which have capacities ranging from 30,000 to 100,000 m^3. For the recapture, larger sieves would have to be employed. This may be addressed in part by reducing the volume needed to fumigate, and hence the total amount of methyl bromide by inflating balloons in the holds.

The temperatures during this trial were warm. Ships often need to be fumigated in cooler weather. Phosphine efficacy is reduced more by low temperatures then is methyl bromide efficacy. Higher phosphine concentrations does increase mortality, however, higher concentrations cannot entirely compensate for shorter durations, ie doubling the concentration will not half the time needed for control. Ships are heated for painting, and this technique could be used to preheat ships before a phosphine fumigation, to increase the effectiveness of the fumigation.

Another solution to infested empty ships would be to treat the grain as it is loaded with a residual insecticide such as malathion or diatomaceous earth, or to fumigate the grain in-transit with phosphine after the grain had been loaded. However, this approach would require a change in policy and possibly require a change in legislation before these methods could be used to deal with the problem of infested ship holds, in Canada.

All three of these methods could easily be adapted for shipping containers, and some tests with the recapture had already demonstrated its effectiveness. Another hurdle for the phosphine based methods would be the certification that the control is sufficient for quarantine purposes, as most importing countries only recognize methyl bromide as adequate for quarantine treatment.

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Table 1. The survival of eggs in treated ship holds as compared to eggs in untreated ship hold as measured by emerging adults after 5 weeks of incubation at 30EC.

Duration of exposure (h)	Insect	Number of adults emerging from untreated hold vials (mean±SEM)	Survival as compared to untreated hold (%)		
			methyl bromide	Eco$_2$Fume™ PH_3 500 ppm	Horn generator PH_3 1000 ppm
32	Red Flour Beetle	11±1	0.9	0.0	0.0
	Rice Weevil	69±6	0.0	3.0	1.1
	Lesser Grain Borer	70±7	0.0	6.4	3.4
	Rusty Grain Beetle	0.1±0.1	-	-	-
48	Red Flour Beetle	14±2	-	0.0	0.0
	Rice Weevil	55±5	-	0.0	0.0
	Lesser Grain Borer	106±10	-	0.4	0.3
	Rusty Grain Beetle	0.1±0.1	-	-	-
72	Red Flour Beetle	11±1	-	0.0	0.0
	Rice Weevil	96±3	-	0.0	0.0
	Lesser Grain Borer	107±13	-	0.0	0.0
	Rusty Grain Beetle	0.3±0.2	-	-	-