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A Preliminary Report of Sulfuryl Fluoride and Methyl Bromide Fumigation of Flour Mills

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Abstract

As a result of the Montreal Protocol, methyl bromide (MB), a major fumigant for the food industry, is facing a mandatory 100 percent production and import phase out. Millers, food processors and fumigators are looking for replacements. Sulfuryl fluoride (SF) is one replacement strategy that was recently labeled for the food market. This presentation summarizes research that is underway to compare the effectiveness of SF and MB under real world conditions. Since 2005 two SF and two MB fumigations have been completed in four different flour mills. Additional fumigations are currently underway in 2006 and will be included in the final presentation. All life stages (eggs, larvae, pupae, and adults) of two major pest species, Indianmeal moth, *Plodia interpunctella* (L) and red flour beetle, *Tribolium castaneum* (Herbst) were used in bioassays exposed during fumigations. Insect monitoring (moth flight and beetle dome traps) was conducted before and after the fumigations to determine the existing pests population and rebound rates. Current results indicate 100 % mortality of larval and adult stages of both species for both fumigants. In addition, SF had 100% mortality of the pupal stage, but low initial survivorship of the egg stage. The majority (99.3 %) of RFB larvae from treated eggs died before the adult stage. MB had 100 % mortality of IMM pupae and RFB eggs but extremely low RFB pupal survivorship (0.4 %) in one facility and 95.4 % mortality of IMM eggs in the other.

Key words: methyl bromide, sulfuryl fluoride, red flour beetle, Indianmeal moth, fumigation.

Introduction

Fumigation is the preferred method to control insects in grain and food processing facilities. It generally perceived to achieve 100 % mortality of target pest, can be done in a short period of time, and there is no need to remove equipments during treatment. The major structural fumigant currently used is methyl bromide (MB). MB is the most widely used fumigant for post harvest and quarantine treatments, however it is an ozone depleting substance, which is facing a mandatory 100 percent production and import phase out (UNEP, 2000, Zettler et al., 1989; Zettler and Cuperus, 1990).).

The phase-out of MB as the major fumigant for use in structural fumigation has caused the industry to seek alternative pest control measures.

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A variety of alternatives such as physical control using heat and chemical control using alternative fumigants such as ECO2Fume® (98 % CO_2 with 2 % phosphine) or Profume® (sulfuryl fluoride (SF)) have been suggested as alternatives for MB but few studies been conducted with direct comparison under field conditions.

Our study focuses on MB and one MB alternative, SF. SF has long been used to treat dry wood termites in structures under the trade name Vikane®. SF, trade name Profume® is a broad-spectrum post harvest fumigant being developed by Dow AgroSciences. The two objectives of this study include: 1. Examine fumigant efficacy by monitoring insect mortality during fumigation. When possible, obtaining replicated data from various facilities for comparative purposes of fumigant type or structure type and 2. Monitoring pre- -and post-fumigation insect population levels to determine insect rebound after fumigation.

Materials and methods

Pre- and post-fumigation monitoring

Red flour beetle, *Tribolium castaneum* (Herbst)(RFB) dome traps (Storgard®) with RFB/CFB pheromone plus food-oil attractant (15 drops) applied to an absorbent pad and Indianmeal moth, *Plodia interpunctella* (L) (IMM) flight traps (NoSurvive®) with Bullet Lure™ were placed inside (3 traps of each type per floor) and outside of facilities (2 traps of each type) 1-2 weeks prior to the fumigation. All traps were removed during fumigation and were replaced immediately after the building was ventilated. Monitoring continued 2, 4, 8 and 12 weeks after fumigation.

Facilities and fumigation

Four flour mills in the Midwest of U.S. were used to conduct the fumigations. These facilities varied in size with the smallest consisting of 6 floors under fumigation and the largest, 10 floors. The fumigations were conducted by commercial fumigation companies, independent of the university. Additional monitoring by the university was conducted during both SF fumigations and one MB fumigation (MB 2). Data collected during the fumigations included weather, internal environmental conditions, and concentration. Two monitoring lines were placed on each floor of a mill. The concentrations were read using Purdue's semi-automatic gas monitoring system. Gas samples were drawn through tubing, passed the monitor, and routed back to the 1st floor of the mill. A summary of the fumigation data is presented in the paper title "Modeling the Structural Fumigation of Flour Mills and Food Processing Facilities" by Maier et al. presented at this meeting.

Insects for bioassay trays

Red flour beetle *Tribolium castaneum* (Herbst) (RFB) and Indianmeal moth, *Plodia interpunctella* (L) (IMM) were cultured at laboratory incubator under 30 °C and 72 % r.h. Stock RFB colonies were maintained on a flour/yeast diet (75 % flour and 25 % yeast) in glass jars (800 ml) sealed with a double layer of filter paper for a lid. To obtain RFB eggs, 100 adults from the stock colony were placed in a soufflé cup (162.7 ml) (Solo Cup Company, IL) that contained 10 g of flour, and incubated at 30 °C (+/- 0.5 °C), 72 % r.h. Eggs were collected on a sieve (No. 80-mesh, Seedburo Equipment Company, Chicago, IL); while larvae, pupae and adults were collected on a No. 25-mesh sieve. Stock IMM colonies were maintained on a moth diet (2,000 g turkey starter, 145g yeast, 25 g boric acid, 300 ml water and 300 ml honey) in plastic jars. To collect eggs, adults where placed in 800 ml glass jars with 1.17 mm wire screen lid over a 12 oz. plastic cup. After 24 hr the eggs were collected from plastic cups. Larvae pupae and adults were collected directly from colony.

Bioassay trays during fumigation

To determine the efficacy of each fumigant,

bioassay trays for both species were placed throughout the facility during the fumigation. A bioassay tray consisted of four containers attached to a piece of 20 cm^2 cardboard. Each container held a separate insect life stage (egg, larvae, pupae or adult). The containers were either a 1.5 ml micro-centrifuge tube, 100 x 15 mm Petri dishes or 2.5 x 10 cm plastic snap cap vial, depending on the insect life stage (Table 1). To facilitate gas exchange, the lids of the micro-centrifuge tubes and snap cap vials were pierced with a small nail and the opening covered with a fine mesh (0.019 cm opening). Lids of Petri-dishes were also pierced with a small nail. Ten individuals of each life stage were used per container and the appropriate diet was added (Table 1).

Table 1. Container types used for the bioassay trays.

Stage	Container type
Egg	1.5 ml micro-centrifuge tube with 0.5 g flour
Larvae	RFB larvae were placed in Petri-dish with 5 g of flour IMM larvae were placed in 1.5 ml micro-centrifuge tube which contains 0.5 g moth diet
Pupae	Petri-dish- no diet.
Adult	RFB adults were placed in Petri-dish with 5 g of flour IMM adults were placed in 2.5x10 cm plastic snap vials with no diet

Trays were placed in the facility prior to fumigation, as close to fumigant release time as possible. After the fumigation and when it was safe to enter the facility, bioassay trays were collected and returned to the lab for analysis. Mortality of all life stages was determined within 24 h. However eggs were held for a maximum of two months to determine if there was larval emergence and survival to adult stage.

We used two definitions of egg mortality: Type I mortality was defined as either the egg did not hatch or if the egg hatched we considered it a survivor, even if it died before adult stage. Type II mortality consisted of a hatched egg that couldn't successfully make it to adult stage. This included un-hatched eggs and eggs that hatched but fail to reach adulthood.

Results and discussion

Pre- and post-fumigation monitoring

A maximum of 24 IMM and 27 RFB per week were trapped indoors prior to the SF fumigations. Indoor IMM populations dropped to 2 - 3 total IMM captured in the first week post SF fumigation. However, the populations rebounded to 27 captured in week 3. RFB population dropped down to 0 in the first week post fumigation and only a total of 3 were captured by the 4th week after fumigation.

Prior to the MB fumigations, IMM populations monitored indoors/outdoors indicated large population pressures. The maximum total captured 1 week prior to the fumigation was 62 indoors and 14 outdoors. Indoor IMM population dropped to a total of 1 IMM indoors while outdoor populations continued to climb to a total of 36 IMM captured outdoors in the first two weeks post-fumigation. Indoor populations post-fumigation rebounded to pre-fumigation level within one month. In the 9-10th week post-fumigation, there were up to 198 (9th) and 58 (10th) total IMM captured.

Total RFB pre-fumigation counts were 135 indoors and 0 captured outdoors. After MB fumigation, indoors RFB populations dropped to a total of 7-12 in the first week post-fumigation, however, RFB indoor populations rebounded to 75 total captured in the 6th week post-fumigation for one of the facilities but remained low (maximum of 25 RFB per two week period) in the other facility.

Fumigation bioassay

Results indicate 100 % mortality of larval and adult stages of both species for both fumigants

(Table 2 and 3). Methyl bromide had 100 % mortality of IMM pupae in both facilities. However, only one MB facility had 100 % mortality of IMM eggs. The other facility had 88.67 % Type I mortality and 95.4 % Type II mortality. SF had 100 % mortality of IMM pupae. Egg mortality varied depending on facility. One facility had 100 % egg mortality, while the other facility had 99.67 % Type I mortality and 100 % Type II mortality.

RFB pupae suffered 100% mortality during both SF fumigations and 1 MB fumigation (Table 3). The other MB fumigation had nearly 100 % pupal mortality (99.6 %, one pupae survived to adulthood). Type I and Type II egg mortality was 100 % in both MB facilities. SF Type I and Type II egg mortality was extremely high in one facility. However, Type I egg mortality in SF facility 1 was low (Table 3) but all hatched individuals died before adulthood and thus the Type II egg mortality was 100 %.

Current results indicate both SF and MB can kill 100 % of larval and adult stages; however, egg and pupal stages were more difficult to control at the low SF CT levels (CT between 338 and 606 oz/Mcf). Once the SF CT reaches the high dose (CT[3] 606 oz/Mcf) there was no problem to control all life stages. Populations rebounded in all facilities regardless of fumigant type. IMM pressure from outside the facility increased throughout the post-fumigation sampling period and was probably the cause of population rebounds within the facility. Sanitation issues within facilities were probably also critical to rapid population rebound even though all insect stages within the bioassay trays died. Although not reported in this presentation, sanitation levels within the facilities varied considerably and those with the highest sanitation level had the slowest rebound rates. Additionally, poor sanitation can result in decreased trap catch due to decreased interception of mobile individuals and this would be reflected in lower total trap catch (Tsai and Mason, unpublished data).

Table 2. Mortality of Indianmeal moth life stages under sulfuryl fluoride (SF) or methyl bromide (MB) fumigation in four different flour mill facilities.

Facility	Egg		Larvae	Pupae	Adult
	Type I	Type II			
	----------		----------% ----------		
SF 1	100.00	100.0	100	100	100
SF 2	99.67	100.0	100	100	100
MB 1	88.67	95.4	100	100	100
MB 2	100.00	100.0	100	100	100

Table 3. Mortality of red flour beetle life stages under sulfuryl fluoride or methyl bromide fumigation in four different flour mill facilities.

Facility	Egg		Larvae	Pupae	Adult
	Type I	Type II			
	----------		----------% ----------		
SF 1	40.61	100.00	100	100.0	100
SF 2	90.67	99.33	100	100.0	100
MB 1	100.00	100.00	100	100.0	100
MB 2	100.00	100.00	100	99.6	100

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