Improvement of phosphine fumigation by the use of Speedbox

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Abstract

Today, phosphine is turning to be a major fumigant for controlling insects in stored products. However, few limitations, such as low temperatures and relatively long exposure time, limit the phosphine use. In order to improve phosphine application, a special devise, containing a heater and a ventilator, called "Speedbox" has been developed by Detia Degesch GmbH Germany. For studying the effectiveness of phosphine fumigation using Speedbox, we have conducted two kinds of experiments: one in a fumigation room (Pilot) and other in commercial warehouse. For pilot fumigation, adults, pupae and late larvae of *Sitophilus oryzae,*, *Rhyzopertha dominica, Oryzaephilus surinamensis*, *Trogoderma granarium* and *Callosobruchus maculatus,* and all stages of *Tribolium castaneum* Herbst, *Plodia interpunctella* and *Ephestia cautella* were used as test insects. One to three Degesch Plates (about 2-6 g of phosphine gas per m^3) were used. Exposure time was 1 to 3 days. The phosphine concentration was monitored by Bedfont device model 415. At 4 g/m^3 for 48 h a maximum of phosphine concentration of 1460 ppm was reached. The total mortality of all tested insects and stages was recorded, except the eggs of *E. cautella* (98%). The commercial stack fumigation was done at the dosages of 2-4 g/m^3, exposure time of 2-4 days and commodity temperatures of 6-17ºC. At a target concentration of 4 g/m^3, 2 hours after beginning of the treatment, the concentration of the gas has reached 414 ppm, with a maximum of 1480 ppm. The total mortality of tested insects at adult, late larvae and pupae stages was recorded. The use of Speedbox allows one-day decrease in the plates degassing time, recirculation of the gas and its event distribution in the treated space and controlling major stored product insects for shorter exposure time at low temperatures.

Keywords: Fumigation; Posphine; Speedbox; Stored-product insects

1. Introduction

In the post methyl bromide era, phosphine is turning to be a major fumigant for controlling insects in stored products. However, few limitations, such as low temperatures and relatively longer exposure times in comparison to methyl bromide, limit the use of phosphine. Some techniques for direct application of gaseous phosphine from cylinder (ECO_2FUME, $VAPORPH_3OSTM$ Phosphine) and on-site generator sources (Horn generator, Chinese generator, QuickPHlo-R phosphine generator, QuickPHlo-C technology and the Degesch Phosphine Generator) and others have been developed to solve these problems (Williams et al., 2000; Mathews and Luzaich, 2003; Waterford and Asher, 2003; Waterford, 2004; Horn and Horn, 2006; Steuerwald et al., 2006; Rajendran and Sriranjini, 2007; Ryan et al., 2010). Each of them aimed for different purposes and has advantages and disadvantages. In order to improve phosphine application, especially for low temperatures and for shorter treatment time, a special devise, called "Speedbox" has been developed by Detia Degesch GmbH Germany (Jakob et al., 2006). The Speedbox is a waterproof aluminium box containing a heater and a ventilator. The Speedbox has been designed to be used exclusively with Degesch Plates®. For studying the effectiveness of phosphine fumigation using Speedbox, we have conducted two kinds of experiments: one in a fumigation room (pilot) and other in commercial warehouse.

2. Materials and methods

2.1. Experiments in the fumigation room

The Speedbox was connected to the fumigation room of 15-m^3 volume filled with wheat grain bags by 30% of the space. One to three Degesch Plates were used. One Degesch Plate contains 56% of magnesium phosphide, weighs 117 g and evolves 33 g of phosphine gas (about 2 g of phosphine gas per m^3). The target concentration was 2 to 6 g of phosphine gas per m^3. The plates were heated to 36ºC into

the Speedbox. The produced hydrogen phosphide was blown in the fumigation room and was pumped out from the room to the Speedbox for recirculation. The range of exposure time was 1 to 3 days. The phosphine concentration was monitored during all the treatment by Bedfont device model 415. Six phosphine gas-sampling points were located at the top, middle and bottom of the fumigation room space, at the point of entry of phosphine gas into the room and at two places between the bags containing wheat. The temperatures of the inter-granular air and of the room space were also recorded. Adults, pupae and late larvae of rice weevil *Sitophilus oryzae* (L.), lesser grain borer *Rhyzopertha dominica* (F.), cowpea weevil *Callosobruchus maculatus* (F.) (both pupae and late larvae inside the grain), saw-toothed grain beetle *Oryzaephilus surinamensis* (L), khapra beetle *Trogoderma granarium* Everts and all stages of Indian meal moth *Plodia interpunctella* (Hübner), tropical warehouse moth *Ephestia cautella* Walker and red flour beetle *Tribolium castaneum* (Herbst) were used as test insects. The test insects were placed between the bags in three replicates. The control insects were kept outside of the fumigation room under the same temperature conditions. The mortality of external stages was counted 24 h, a week and a month after treatment. The mortality of internal stages was counted a week, 2 weeks and a month after treatment. The egg hatching was counted 3 and 7 days after treatment. The progeny of tested insects at all stages were counted 6 weeks after treatment. All tested insects were reared and maintained after treatment under laboratory conditions at 28±0.5ºC and r.h. of 65±5%.

2.2. Experiments in commercial warehouses

The fumigation was carried out in commercial warehouses in the South and in the Center of Israel. Bags of wheat grain, rice, sunflowers, beans, peanuts, pistachio and nuts, each one of 40-50 kg weight, were hermetically sealed using plastic sheets. The range of stack volume was 15 to 60 m^3. The range of outdoor temperature was 15º to 23ºC at the beginning of the experiments and 8º to 25ºC during the experiments. The temperature of the above-mentioned treated products was 6º to 17ºC at the beginning of the experiments and 6º to 19ºC during the experiments. The Degesch Plates were used. The Speedbox was connected to the stack. The number of the used plates was counted according to the target concentration of phosphine gas. The plates were put into the Speedbox and were heated to 36ºC. The produced hydrogen phosphide was blown into the stack and was pump out from the stack to the Speedbox for recirculation. The dosage of the phosphine gas was 2-4 g/m^3. During the experiment, the concentration of phosphine was monitored by Bedfont device model 415. The exposure time was 2 to 4 days. The test insects were *S. oryzae*, *R. dominica*, *O. surinamensis*, *T. castaneum*, *E. cautella*, *P. interpunctella*, *T. granarium* and *C. maculatus*. All the insects were tested at the stages of adults, late larvae and pupae (while the insects were inside the kernels for relevant species). The test insects were inserted into the stack in three places. The control insects were kept outside of the stack in the same warehouse. The mortality of external stages was counted 24 hours, a week and a month after treatment. The mortality of internal stages was counted a week, 2 weeks and a month after treatment.

3. Results

3.1. Experiments in the fumigation room

The results showed, that at a target concentration of 4 g/m^3 and exposure time of 48 hours, the effective concentration of phosphine was reached in a short period. Half hour after beginning of the fumigation 95 -115 ppm of phosphine was recorded. After 15-17 hours, the maximum concentration of the gas has reached 1460 ppm. The gas concentrations in 6 sample points in the space and in the commodity were very similar. The total mortality of adults, larvae (late) and pupae of *S. oryzae*, *R. dominica*, *O. surinamensis T. castaneum, T. granarium, C. maculatus, P. interpunctella and E. cautella* was recorded. For *T. castaneum, P. interpunctella and E. cautella* 100, 100 and 98% of egg mortality was achieved, respectively.

3.2 Experiments in the commercial warehouses

In the field experiment (the 60-m^3 stack of wheat grain bags, the target concentration of 4 g/m^3, the exposure time of 2 days and commodity temperature of 17- 20ºC) the concentration of phosphine has reached 414 and 1480 ppm after 2 and 24 hours respectively. The total mortality of adults of *S. oryzae*, *R. dominica, O. surinamensis*, *T. castaneum, C. maculatus* and *T. granarium*, as well as larvae and pupae of *P. interpunctella*, *E. cautella* and above-mentioned coleopterans was recorded (Table 1). The same

results were obtained after fumigation of the 15-m^3 stack containing various grains, at the dosage of 2 g/m^3, exposure time of 4 days and commodity temperature of 6-8ºC.

Table 1 Effect of phosphine fumigation (4g/m^3 for 48h) using Speedbox against major stored- product insects.

Insect	Stage	Mortality (%)	
		Pilot	Field
Sitophilus oryzae	adults	100	100
	pupae	100	100
	larvae late	100	100
Rhyzopertha dominica	adults	100	100
	pupae	100	100
	larvae late	100	100
Oryzaephilus surinamensis	adults	100	100
	pupae	100	100
	larvae late	100	100
Tribolium castaneum	adults	100	100
	pupae	100	100
	larvae late	100	100
	eggs	100	-
Trogoderma granarium	adults	100	100
	pupae	100	100
	larvae late	100	100
Callosobruchus maculatus	adults	100	100
	pupae	100	100
	larvae late	100	100
	eggs	100	-
Plodia interpunctella	adults	100	100
	pupae	100	100
	larvae late	100	100
	eggs	100	-
Ephestia cautella	adults	100	100
	pupae	100	100
	larvae late	100	100
	eggs	98	-

Pilot: fumigation room of 15-m^3 volume filled with wheat grain bags by 30%. Field: stack of grain bags, 60-m^3 volume. The mortality of external stages was counted 24 hours, a week and a month after treatment. The mortality of internal stages was counted a week, 2 weeks and a month after treatment. The egg hatching was counted 3 and 7 days after treatment.

4. Discussion

The current results show that the Speedbox allows significantly decreasing the period of phosphine release from the Degesch Plates. The maximum of phosphine concentration in the treated area was achieved just after 12-17 hours from the beginning of the fumigation, depend on target concentration. As was established by Jacob et al. (2006), without the Speedbox the degassing rate of the Degesch Plates after 24 hours was only 60%. Therefore, the Speedbox allows getting the effective concentration of phosphine in a shorter period and thus to decrease the exposure time. The Speedbox allows also recirculation of the gas for its even distribution in the treated stack.

All developmental stages of the tested insect, except eggs, were totally killed at a target concentration of 4 g/m^3 for 48 hours both in pilot and field fumigations. The eggs were found to be the most tolerant developmental stage of the tested insects. Our data is consistent with the results obtained by Mills et al. (2003).

It is important to underline that in some field fumigations the temperatures of the outdoor and treated products were as low as 8-16ºC and 6-8ºC, respectively. Despite the strong gas sorption by the treated commodities, especially with high lipids content, the concentration of phosphine during the treatment

was high enough and total mortality of tested insects was achieved. The current results are consist with the findings from Jacob et al. (2006) studies, that with the Speedbox, only negligible degassing differences were observed between 10ºC and 20ºC.

To conclude, the Speedbox allows:

- To optimize the phosphine fumigation of stacked bags in controlling all developmental stages of the major stored product insects.
- To decrease significantly the period of phosphine release from the Degesch Plates and the exposure time.
- To enable effective phosphine fumigation at low temperatures.
- To achieve even distribution of the gas in the treated space.
- The advantages of the Speedbox open novel possibilities for phosphine fumigation also as quarantine treatment.

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