Intermittent application of phosphine and carbon dioxide to control phosphine-resistant pests in horizontal storage containing bagged wheat

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Abstract

Fumigation of an entire horizontal storage containing bagged wheat with phosphine at 3.3 g/m³ by using conventional aluminium phosphide formulation failed to control Rhyzopertha dominica, Sitophilus zeamais and Latheticus oryzae completely. A second fumigation with a total of phosphine 1.0 g/m³ plus carbon dioxide 0.076 kg/m³ by using a phosphine generator in an intermittent manner gave complete control of adults of Rhyzopertha dominica of phosphine-resistant strains in bioassays but naturally occurring adults of Rhyzopertha dominica survived. The grain stack was then covered with PVC sheet and a third fumigation by total phosphine 1.21 g/m³ plus carbon dioxide 0.2 kg/m³ also in a split application gave complete control of the natural infestation.

Introduction

Phosphine as a fumigant of stored products has been used for more than 30 years in China (Lin and Lin, 1994). For many reasons (Desmarcheler and Wollgemuth, 1984), such as poor gastightness, short exposure time, and so on, some fumigations in practice were failed. Because of those facts some important species of stored grain insects had been selected by phosphine, therefore phosphine resistance of stored grain insects developed. How can we control the phosphine resistant insects and delay the development of resistance? Because there are no fumigants to take the replace of phosphine in grain industry, the improvement of application technique for phosphine fumigation is very important for delaying the resistance development. Many experts had reported the methods of mixing of phosphine with carbon dioxide for fumigation and split application of phosphine. Some successful fumigation had been achieved. The gastightness of storage in phosphine fumigation is one of the most important factors. Unless storage enclosures are sealed to an adequate degree of gastightness, it is difficult for phosphine fumigation to achieve complete control of target infestations (Wallace, 1986).

The current studies were carried out in a horizontal storage in which a standard fumigation failed. Following the failure of the initial standard fumigation, the second fumigation was undertaken to evaluate the phosphine generator that applied a split application of phosphine with carbon dioxide to the entire storage in the standard condition. In the third fumigation, combinations were applied to a bagged stack inside the storage.

Materials and Methods

Test 1. Standard fumigation of a horizontal storage

Storage

The first fumigation was conducted in May 1997 in a horizontal storage of brick and concrete construction approximately with a volume of 3952.1 m³ (50.5 × 18.2 × 4.3 m). The doors and windows were sealed with polyvinyl chloride sheeting.

Grain

The storage contained 2519 tons of bagged wheat in a stack about 2000 m³. The mean grain temperature measured by thermocouples was 31°C and the mean grain moisture, estimated by oven drying method at 110°C for one hour, was 12.4%.

Application of phosphine

Tablets containing aluminium phosphide were placed in trays on top of the grain stack and allowed to generate phosphine. The application rate of aluminium phosphide was 10 g/m³ which generated phosphine 3.3 g/m³

Test 2. Split application in a horizontal storage

Storage and Grain

The same storage and grain were used in this fumigation.

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but the current work was undertaken in August 1997

**Application of phosphine**

A phosphine generator was used to generate a mixture of phosphine plus carbon dioxide. Aluminum phosphide tablets were added to water in a reaction vessel purged with carbon dioxide and the mixture was ducted into the storage. The total application rate was 1.0 g/m² phosphine plus 0.076 kg/m² carbon dioxide with the first half at commencement and the second half on the 7th day.

**Bioassays**

Bioassays (Anon. 1982) were carried out by using adults of *Rhyzopertha dominica* which were cultured in the laboratory on whole wheat of 12.5% grain moisture at 30°C and 60% relative humidity. The resistance factor in the FAO test was × 190 so the strain was termed as low level resistant.

Young (40 days) adults (30) were counted into cages made of glass tubing (10mm diameter × 70 mm) along with 40 grams of broken wheat and both ends were covered with nylon mesh (mesh number 60 = 0.3mm). A total of 15 cages were placed on the stack and 3 cages were kept as a control. Mortality of the adults was observed 14 days after completion of the fumigation. *Phosphine concentrations* Gas concentrations were monitored by using samples drawn via polyethylene tubing connected to four points in the upper part of the stack, four in the middle and four in the lower.

Concentrations were measured by using phosphine detection tubes incorporated with colloidal nitrate of silver manufactured in Henan Province, and by using phosphine fumigation monitor, too (EC80 Bedfort made in England).

The rate of leakage from the storage was estimated in the interval after the generation and release of phosphine was completed. Linear regressions were calculated of the natural logarithm of concentration of phosphine (mg/L) against time (days). The exponential of the regression coefficient was calculated and the proportion of the phosphine concentration remaining in successive days was given. The percentage loss per day due to leakage was calculated by subtracting the percentage loss per day due to sorption which had been determined in earlier experiments.

**Carbon dioxide concentrations** Carbon dioxide was monitored through using the same sample tubing, but with carbon dioxide detection tubes incorporated with hydrazine and crystal violet manufactured in Henan Province.

**Test 3. Split application in a sheeted stack**

**Storage**

The gram stack inside the storage was covered with PVC sheeting (thickness 0.02 mm) and weighted to the floor at the perimeter with sand snakes.

**Application of phosphine**

The phosphine generator was used to apply a total dosage of phosphine 1.21 g/m³ plus carbon dioxide 0.2 kg/m³ in a split application. The first half was applied at commencement and the second on the 14th day.

**Results and Discussion**

**Test 1**

No detailed observations were made of the phosphine concentrations but *Rhyzopertha dominica*, *Sitophilus zeamais* and *Latheticus oryzae* survived.

**Test 2**

Data on the phosphine concentrations are given in Figure 1 and on carbon dioxide concentrations in Figure 2.

![Fig. 1. Phosphine concentration of intermittent fumigating stack without PVC in a gram house](image-url)
The phosphine concentrations initially peaked on day 2. The rate of loss from day 4 to day 6 was 22% per day and from day 8 to 13 it was 34% per day. With a rate of sorption of 5% per day, the leak rates were 17 and 29% respectively. These rates are higher than for comparable storages in the Xinyang Pingquiao Depot.

From day 1 onwards, the carbon dioxide concentrations were similar at different heights in the stack, suggesting good mixing.

The mean concentration on day 13 was 0.032 mg/L which was less than the Australian standard of 0.05 mg/L.

All *Rhyzopertha dominica* adults in the bioassays were dead at the time of assessment but live adults of *Rhyzopertha dominica* were present in the stack. They may have survived the fumigation as adults or possibly they developed from pupae during the fumigation. In either case, they represent a fumigation failure.

**Test 3**

Data on the phosphine concentrations are given in Figure 3 and on the carbon dioxide fumigation in Figure 4.

The rate of loss of phosphine from day 4 to 13 was 8% per day and from day 20 to 31 it was 10%. Assuming a sorption rate of 5% per day, a leak rate of 3% per day was suggested. The mean phosphine concentrations 0.33 mg/L on day 11 exceeded the Australian specification of 0.3 mg/L at day 10; 0.66 mg/L at day 15 exceeded 0.05 mg/L at day 14; 0.54 mg/L at day 22 exceeded 0.03 at day 21 and 0.2 mg/L at day 31 exceeded 0.02 at day 28. No remifestation was observed.

There were significant differences between Ct value of stacks covered with PVC sheet and without PVC sheet (Table 1). On the 13th day after fumigation, the average Ct value in stack covered with PVC was 14.4, while the average Ct value in stack without PVC cover was only 1.07. Therefore gastightness is of great importance to a successful fumigation.
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Fig. 4. Carbon dioxide concentration of intermittent fumigation in a stack with PVC sheet

Table 1. Comparison of Ct value (mg·h/L) of stacks covered with and without PVC sheet.

<table>
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<th>Days</th>
<th>Without PVC</th>
<th>With PVC</th>
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<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Middle</td>
</tr>
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<td>1</td>
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</tr>
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<td>Total</td>
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</table>

Acknowledgement

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References


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