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PHOSPHINE RECIRCULATION SYSTEM IN A METAL BIN

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ABSTRACT

Distribution of phosphine generating tablets requires grain transfer from one bin to another one and also leaves undecomposed aluminium phosphide in grain mass. Phosphine recirculation systems (PRS) avoid the negative consequences of direct addition to grain. PRS consists of a special constructed phosphine generator, fan, pipework and groups of ventilation channels in the bin floor with perforated covers. One pipe connects outlet of fan to the inlet of the channels of ventilation system. The second pipe joins inlet of phosphine generator with the grain headspace. A metal bin was equipped with PRS. Rice (paddy, 1500 tonnes) was stored in the bin. Aluminum phosphide tablets equivalent to a dosage of 1.37 g phosphine per m3 were put into the phosphine generator. The recirculation fan was operated for 66 h, with another 2 h to vent the phosphine out of the grain mass. Tests showed the very uniform distribution of phosphine in different parts of the grain mass. Almost all adults of *Sitophilus granarius* L. (96.1%) and also preimaginal stages as hidden infestation in the grain (99.7%) were dead after fumigation.

Key words: phosphine, recirculation system, grain, metal bin, beetle.

INTRODUCTION

If grain is to be fumigated directly with phosphine-generating tablets, the grain must be moved from one bin in another one and tablets must be added into the grain stream. After such fumigation the grain mass contains remnants of the decomposition of tablets in which partly undecomposed aluminum phosphide is often present. It is not safe to work with such grain. The recirculation of phosphine through the grain mass avoids the costs for the movement of grain as well as eliminating hazardous residues of decomposition of tablets in the grain. In this demonstration of the technique, we decided to use a metal bin, a type that have recently been built in Russia in large numbers to store grain.

MATERIALS AND METHODS

Tests were carried out in a metal bin: volume 2919 m^3, diameter 13 m, height of wall 21 m and of the roof cone 3 m. The volume occupied by paddy rice, 1500 t, was 2653 m^3 and the volume of air between kernels was about 1592 m^3, giving a total air volume in the loaded bin of about 1858 m^3.

The metal bin was equipped with a special recirculation system which included: a specially constructed phosphine generator, fan, pipework and a group of ventilation channels in bin floor with perforated covers (see Fig. 1). A duct connected the outlet of the fan and inlet of the ventilation system. A second pipe joined the inlet of the phosphine generator with the bin headspace.

During the tests the temperature of the ambient air ranged from 1 - 6ºC during the daytime to –2 - 4ºC at night. The temperature of the grain ranged in different parts from 14 to 25ºC, average. approximately 19.3ºC. During the recirculation, the warm air from grain was moved through the phosphine generator, providing the temperature of the air inside the generator at the level of 12-13ºC.

Fig. 1- Metal bin equipped with phosphine recirculation system.

Tablets based on aluminum phosphide active ingredient were used as a source of phosphine. At the beginning the generator was charged with tablets at a dosage of 2.74 g m^{-3} (0.91 g m^{-3} phosphine). After 24 hours of exposure we added additional 1.37 g m^{-3} tablets (0.46 g m^{-3} phosphine), bringing the total dosage of tablets to 4.11 g m^{-3} (1.37 g m^{-3} phosphine).

Parameters of gas flows in the recirculation system were as follows: air flow 5758 m^3 h^{-1}, equivalent to 3.1 air changes per hour. The face velocity of air in the silo was 1.2 cm s^{-1}. After 66 h exposure, the remaining phosphine was vented over 2 h.

The assessment of the fumigation of grain was carried out on the distribution of phosphine gas in the recirculation system as well as on the mortality of adult and preimaginal stages of *Sitophilus granarius* L. in bioassays. Grain with preimaginal stages was incubated at 25 ºC and the emerged adults were assessed every week over 7 weeks.

RESULTS AND DISCUSSIONS

From the data shown in Table 1, it is evident that the recirculation system provided the ideal distribution of phosphine to the different parts of grain mass. The low phosphine concentrations after 18 h compared with the dosage applied (applied 0.91, observed 0.14 g m^{-3}) may be explained by high absorption by the paddy rice as well as leakage. Addition of further phosphine by the generator after 24 h maintained the gas concentration at the same level (0.14 g m^{-3}) during next 24 h.

After fumigation almost all adults of *S. granarius* (99.1%) were killed (see Table 2).

Table 1. The distribution of phosphine in a recirculation system

Measuring point	Phosphine concentration (mg m^{-3}) after							
	18 h	21 h	24 h	27 h	32 h	43 h	48 h	66 h
Grain, depth of 0.1 m,								
from the bin wall: 0.1 m	42	140	140	140	140	140	140	42
3.2 m	42	140	140	140	140	140	140	42
6.5 m	42	140	140	140	140	140	140	42
Grain, depth of 2.0 m,								
from the bin wall: 0.1 m	42	140	140	140	140	140	140	42
3.2 m	42	140	140	140	140	140	140	42
6.5 m	42	140	140	140	140	140	140	42
Inside the pipe in front of the generator	42	140	140	140	140	140	140	42

Table 2. The effectiveness of the fumigation of *S. granarius* adults

Measuring point	Mortality, %	
	Control	Fumigated
Grain, depth of 0.1 m,		
from the bin wall: 0.1 m	0	100
3.2 m	0	100
6.5 m	0	100
Grain, depth of 2.0 m,		
from the bin wall: 0.1 m	0	96.7
3.2 m	0	100
6.5 m	0	100
Near the roof of the bin	0	96.7
Average	0	96.1

The data on preimaginal stages as hidden infestation of the grain are given in Table 3. On average 452 beetles emerged from the kernels in the control bioassays over 92 days of the observations. A range of 0 to a maximum 4 beetles (average 1.6) hatched from the bioassays which were distributed in different parts of the grain mass under fumigation. This corresponds to a mortality of the preimaginal stages of 99.7%.

The test described here have shown that use of the method of recirculation of phosphine through the grain mass for the purpose of its disinfestation in metal bins is an effective method with good prospects.

Table 3. The effectiveness of the fumigation of preimaginal stages of *S. granarius*

Measuring point	The number of emerged adults		Mortality, %
	Control	Fumigated	
Grain, depth of 0.1 m,			
from the bin wall: 0.1 m	452	1	99.8
3.2 m	452	0	100
6.5 m	452	4	99.1
Grain, depth of 2.0 m,			
from the bin wall: 0.1 m	452	0	100
3.2 m	452	2	99.6
6.5 m	452	2	99.6
Near the roof of the bin	452	2	99.6
Average	452	1.6	99.7