0413

Research about the Technologies of PH_3 Recirculatory Fumigation in Squat Silos in the Ecological Regions of Medium Temperature and Low RH

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Abstract: Because regions of medium temperature and low RH are suitable for growth of insect populations throughout the year, we need to treat stored grain according to the infected portions and time. In this paper we summarize three methods of integrated control to kill pests and prevent pest resistance.

Key words: fumigant, fumigation, squat silo, recirculation fumigation, integrated control

Introduction

Squat silos for long-term grain storage have been built in China since 1998 when the government invested to build many new grain warehouses and to extend existing grain ones. Because the grain bulk is high and the volume large, it is very difficult to achieve even diffusion of fumigant, where even, quick and effective fumigation is needed to control pests. Moreover, insects in the South of China and moisture content in the North are basic problems. The environment of high temperatures and the small temperature difference in the south, particularly in the ecological regions of the medium temperature and low RH, is very suitable for the growth and reproduction of insect pests throughout out the year. Therefore, the basic work in the warehouse is controlling stored grain pests. Although mechanical equipments in the squat silos are convenient for daily operations, they are also a good habitat for growth of stored grain pests. Here we summarize the fumigation technology which can kill pests quickly and completely at low dosage, and which can be used safely. At the same time, it overcomes the problems of uneven distribution of fumigant, high dosage and incomplete pest control. The technology will be ideal for fumigation in tall grain bulks.

Materials

Experimental Silos

No. 18, 20 and 21 silos have the same design dimensions, the stored grain is medium grade wheat produced in Henan. The diameter of squat silos is 25.0 m, with a height of 15.0 m grain; other detail contents are shown in table 1.

Table 1 Test basic information of stored grain warehouse

silo No.	Input time	Quantity (t)	Grain temperature (℃)	Moisture content (%)	impurity (%)	unitweight (g/L)	*Sitophilus zeamais*	*Rhizoperth adominica*, *etc.*	*Sitotroga cerealella*
							(number/kg)		(number/m^2)
18	2007	6000	21.6	12.5	0.5	778	25	0	0
20	2006	6000	15.8	12.2	0.6	785	9	0	3
21	2006	6200	19.2	12.1	0.4	788	5	6	0

Notes: *Rhizopertha dominica*, *etc.* in Table 1 includes high resistance pests such as *Cryptolestes ferrugineus* and *Tribolium castaneu*

Instruments

Beijing OPI Digital Stored Grain monitoring System, Shenyang 'Fengshou' 56% AlP tablet, PH_3 concentration detector (Beijing jiahua HL-210) and alarm device, phosphine-generator (Zhengzhou weilai), DSS fixed recirculation System of Shenzhen Automation Engineering Co., Ltd.

Method

Layout of Gas Detecting Point

The layout for detection of gas concentration are set between two cable lines in the external aeration tubes, and divided into three layers (upper, middle and bottom). The distance from the ground is 1.0, 6.0, and 12.0 m. The spatial concentration of gas is detected from the

Kunming Warehouse Directly under Central Grain Reserves, Kunming, Yunnan

test tube in the fumigant container next to the recirculation fan.

Airtightness of Silos

Air vents and axial flow fan mouth are sealed with covers, the doors of silos are sealed with 0.15 mm polyethylene approved for grain. Before loading grain, the manual and electric valves at the bottom of the silos must be well closed. The pressure test results of the pilots are that the hermetic time of No. 18, 20 and 21 silos are 120 s, 110s, 117s, which are longer than the 60s given in the Technical Regulations of grain storage.

Methods

Fumigation of New Arrival Grain in No. 18 silo

As the grain in No. 18 silo is inputted from July to October, its temperature is high, the quantity is large, the period of input is long and pest density is high. The pest density is 25/kg when the silo is full. The first thing we do is to drive the pests to the surface of grain bulk through aeration, and simultaneously to balance the temperature of grain to prevent condensation of water vapor. Then 16.0 kg tablets are distributed on the grain surface, and the air is recirculated to balance the phosphine gas concentration.

Fumigation during Grain Storage in No. 20 Silo

The grain temperature is uniform during grain storage in No. 20 Squat silo with a average temperature of 16.5℃. Fumigation combined the distribution of fumigant on the grain surface with PH_3 gas supplied from outside of the silo. The consumption of tablets was 8.0 kg for each stage.

Fumigation for the High Resistance Pests in No. 21 Silo

C. ferrugineus and T. castaneum infested the grain in No. 21 squat silo. Because they have high resistance, we applied intermittent recirculation fumigation to kill the pests. The method is supplying fumigant from outside the silo and maintaining effective concentrations for at least 18 days, then stopping supplying for a period of time, finally replenishing fumigation on the 25th day. The amount of fumigant in the first stage is 14.0 kg and 8.0 kg at the second stage.

Detection of PH_3 Gas Concentration

HL – 210 PH_3 gas concentration detector started to detect PH_3 gas on the second day after the first stage of finishing fumigant distribution on the surface of grain. When the concentration reaches effective concentration, the detection frequency changes with the phosphine concentrations (for example, when PH_3 concentration is higher than 500 mL/m^3, we will detect it once 2 – 3 days), until the concentrations is below the efficient concentration).

Ventilation and Pest Control Inspection

After finishing of the fumigation, four axial fans begin to ventilate grain bulk. Four days later, when the concentration is below than 0.2 mL/m^3, we inspect the result of fumigation through sampling the grain at points of high pest density or high temperature, and then inspect the points again a month later, making a detailed record at each time.

Conclusion and Analysis

PH_3 Gas Concentrations in Each silo

Fumigation of No. 20 and 21 silos took place in 2006, while No. 18 silo was fumigated in 2007. The maximum concentration in each silo was ⩾500 mL/m^3 (the instrument records 500 mL/m^3 for concentrations more than 500 mL/m^3).

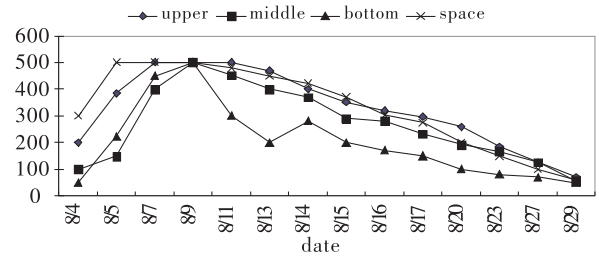

Fig. 1 Gas concentration in No. 18 silo

The concentration of PH_3 in No. 18 silo reached effective concentrations (Fig. 1) on the 2nd day, and peaked on the 4th days, then attenuated gently. The space and upper PH_3 gas concentration were always higher than others. Concentration of PH_3 was higher than 150 mL/m^3 for 14 days and higher than 100 mL/m^3 for 20 days. Because the grain temperature was higher, the AlP tablet evaporated easily. At the same time ventilation drove pests to the surface, which facilitated pest kill on the surface, which satisfies our purpose. This method is easy, efficient and saves costs.

In No. 20 silo, the concentration of PH_3 reached effective concentrations (Fig. 2) on the 1st day, and peaked on the 3rd days. The space and upper PH_3 gas concentration attenuated gently, and concentration was higher than 150

mL/m^3 for 16 days, and higher than 100 mL/m^3 for 20 days. At the same time CO_2 was used to help the fumigant diffuse into grain bulk quickly, so the airtight time is shortened, while the fumigant on the surface kept evaporating to maintain the concentration. This reached the desired aim.

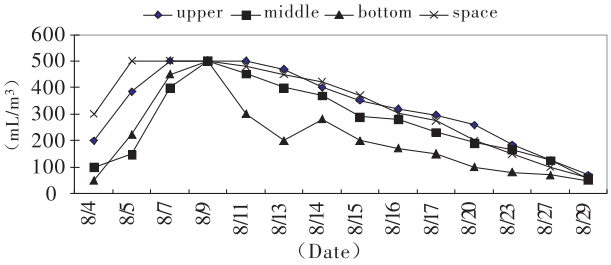

Fig. 2 Gas concentration in No. 20 silo

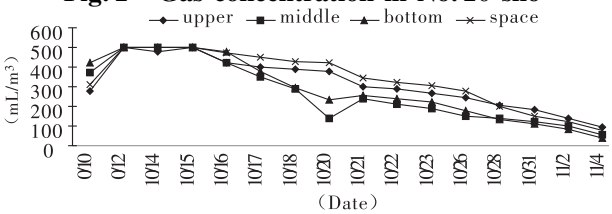

Fig. 3 Gas concentration in No. 21 silo

The concentration of PH_3 reached effective concentration in No. 21 silo on the 1st day (Fig. 3), and peaked at same time. The gas concentration at each layer attenuated quickly. The time of concentration higher than 150 mL/m^3 was 12 days, and that higher than 100 mL/m^3 was 16 days. During the replenishing period, concentration was higher than 150 mL/m^3 for 12 days. As the interval between two applications was 24 days, the eggs of high resistance pests hatched into larvae during this period, so the larval stage with low resistance was killed in the second fumigation period. This two-fold fumigation reduced the consumption of fumigant, and effectively solved the problem of incomplete control of resistant insects.

Controlling Effect and Benefit Analysis

Samples from 5 points in each layer (upper, middle, bottom and space) was inspected, and each silo (No. 18, 20, 21 silo) reached the desired control by different fumigation methods after more than 1 month airtight fumigation. Choosing different methods according to different situation will reduce the fumigation cost and labor intensity, at the same time solving the problem of incomplete kill of high resistance pests.

Table 2. Fumigation efficacy and costs

SiloNo.	Total amount(kg)	CO_2 gas(kg)	sampling afterdiffusion (number/kg)	sampling after 30 days(head/kg)	sampling after 60 days (number/kg)	Operating time(h)	labor (person)	Costs (yuan)
18	16	0	0	0	0	1	6	416
20	16	30	0	0	0	6	4	491
21	22	80	0	0	0	18	2	616

Notes: CO_2 gas 50 yuan/tank of 20 kg, CO_2 gases takes 2.5 yuan/kg, aluminum phosphide cost 26 yuan/kg, excluding labor costs.

Discussion

Choosing the best time to kill pests is important. As the activities of pests relates to stored grain temperature, normally they thrive in summer and reach their peak in autumn. As high temperature always relates to frequent activity, the best time for killing pests is from June to October.

Improving air-tightness of silos, monitoring concentrations of phosphine and replenishing concentrations will achieve the time required for effective concentration.

When grain at out-loading is infected, it can be treated by probing with phosphine formulations. If the grain on the surface is infected, it can be treated by 'Spot' fumigation, which is to cover the infested grain with gas-proof sheets like bell-shape, and to fumigate by probing formulations into areas. Normal more dosage is put on the top and the dosage is 6 – 15 g/m^3.

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