0607

Preliminary Analysis on Effects of Killing Insects and Economy in the Prevention and Treatment for Stored Grain Pests

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Abstract: During the prevention and treatment of stored grain pests, the aims should be to store grain safely and economically. Factors that need to be considered include the different methods of distributing chemicals, application of different fumigating measures, selection of different treatment times, the different pest species and selecting non-fumigation or partial fumigation depending on the assessment of the pest numbers.

Key words: prevention and treatment for insect pests; effects of killing insects; economy

Introduction

The methods and effects of killing insects in the prevention and treatment for stored grain pests have been focused on efficacy, economy and safety. In 1950's, Stern initially described the concept of economic threshold (ET), namely that prevention and treatment measures are applied when the population of pests increases to the specified density which will result in economic loss. Based on ET, Sheng Chengfa further interpreted and described the time of the prevention and treatment, investment and the survival rate of pests in 1989. For controlling pests economically, the question which needs to be answered by scientists is when the specific prevention measures should be applied to reduce the pests whose density is dangerous. In the past several years, we compared and assessed the different methods of using chemicals, the different measures of recirculation fumigation, and the treatment time for recirculation fumigation. We compared recirculation fumigation with non-recirculation fumigation when the kinds of pests and amount are at a low level. Our research shows the relationship between the effects of killing pests and ET when the prevention and treatment for stored grain pests are carried out. The optimal conditions for controlling stored grain pests were investigated.

Comparison of Traditional Fumigation and Recirculation Fumigation

Traditional fumigation using phosphine (PH_3) gas can not kill all pests because of the limited infiltration of PH_3. Better results were obtained after the combination of recirculation fumigation with traditional fumigation to treat the pests in high grain piles. After this, the use of recirculation fumigation became widespread when our old warehouses were reconstructed.

The tests were performed at Qujing Branch of China Grain Reserves Corporation, and the warehouses with facilities were chosen to test recirculation + traditional fumigation. The length of these warehouses was 51.5 m, the width was 19.8 m, and the height of the grain pile was 6.0 m. The grain tested was local round-grained rice produced in 1999. A warehouse of the same size was chosen as a control to carry out the traditional fumigation.

The dosage was 5.7 g/m^3 of aluminium phosphide (AlP) in the traditional fumigation warehouses, and the amount of total amount of AlP in each warehouse was 45 kg. Live pests were seen in the narrow space between two plastic films and the grain piles. The dosage was 3.1 g/m^3 in the recirculation + traditional fumigation warehouses and the amount of AlP in each warehouse was 25 kg, with 15 kg applied at first and another 10 kg added after 5 days. The PH_3 concentrations measured in the recirculation + traditional fumigation warehouses are shown in Table 1.

Samples were taken at intervals of 30 and 60 days after ventilation by means of a deep sampling apparatus. No live pests were found and the mortality rate was therefore 100%. The results show that the technique of recirculation + traditional fumigation can lead to thorough mixing of the PH_3 gas maintenance of high concentrations for long periods, resulting in a higher CT product. Our results suggest that the application of technique of recirculation fumigation can kill the store grain pests totally. The economical a-

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nalysis of using technique of recirculation + traditional fumigation is shown in Table 2.

Table 1. Phosphine concentrations(ppm) in recirculation + traditional fumigation warehouses.

No.	Time of day	Date											
		7.12	7.13	7.16	7.17	7.18	7.19	7.23	7.24	7.26	7.30	8.3	8.6
1	morning	382	557	605	393	403	456	556	455	376	240	181	102
	afternoon	101	402	504	358	–	345	485	–	–	–	–	–
2	morning	243	337	378	332	219	238	320	284	292	288	278	131
	afternoon	185	271	327	268	–	269	311	–	–	–	–	–
3	morninWg	360	271	411	420	332	335	330	411	358	297	192	123
	afternoon	233	472	295	382	–	340	340	–	–	–	–	–
4	morning	411	411	307	301	255	254	249	302	278	231	173	100
	afternoon	201	322	269	297	–	259	234	–	–	–	–	–
5	morning	607	669	620	424	417	395	404	501	420	285	205	110
	afternoon	476	605	561	468	–	556	446	–	–	–	–	–

Table 2. Cost analysis of different methods of fumigation

Cost factor	Recirculation + traditional fumigation	Traditional fumigation
Dosage of AlP	25 kg	45 kg
Cost of AlP	700 yuan	1260 yuan
Wages	150 yuan	270 yuan
Savings	680 yuan (savings rate = 44%)	–
Effects	100% control of pests	Some live pests, need repeating
Other cost	No difference	

Comparison of Recirculation Fumigation in Mixture of PH_3 and CO_2 With Recirculation Fumigation Through Natural Deliquesce in Distributing AlP on the Surface of Grain

The usage of recirculation fumigation with a mixture of PH_3 and carbon dioxide (CO_2) stored in steel cylinder at our testing system showed the good results. Comparison with AlP, the purchase and storage of PH_3 and CO_2 are inconvenient and their price is expensive. It costs too much to perform recirculation fumigation with a mixture of PH_3 and CO_2. CO_2 gas is purchased far from our testing warehouses still cost too much even if the generator of PH_3 gas is applied outside the warehouses. Based on the similar results obtained from the three techniques of recirculation fumigation, we suggest that the best technique for the prevention of infestations and treatment of infested grain should be recirculation fumigation with AlP placed on the surface of grain to react with the moisture in the air to promote release PH_3 gas.

Comparison of Putting AlP on the Blow-holes with Putting AlP on the Surface of Grain

This test was carried out on the blow-holes in one-stored warehouse with high space in 2005, the cloth bags containing AlP on the surface of grain were changed into putting AlP on the blow-holes by means of AlP spreading plates made by ourselves. The number of workers taking part in the toxic environment and the operation time in such environment were reduced. The dosage of AlP was decreased and the effective treatment time was extended because of the enough concentration of PH_3. Therefore, the effects of recirculation fumigation were improved obviously.

The No. 21 and No. 5 warehouses of the Qujing Branch of China Grain Reserves Corporation were chosen as testing warehouses, and the No. 22 and No. 7 warehouses were chosen as control (see Table 3 for details).

Table 3. Detailed information on test and control warehouses

	Warehouse number			
	21	5	22	7
Size(m) (L x W x H)	51 ×20 ×7.8	33 ×20 ×6.8	51 ×20 ×7.8	33 ×20 ×6.8
Grain heigh t(m)	6.1	4.7	6.1	4.7
Grain type	Indica rice	corn	Indica rice	corn
Amount(t)	3,952	2,300	3,935	2,295
Intake (month/year)	5/2003	3/2004	4/2003	4/2004

	Warehouse number			
	21	5	22	7
Moisture content(%)	12.5	13.7	12.8	13.3
Pests(per kg or per m^2)				
Sitophilus zeamais (Motchulsky)	5	4	4	3
Gelichiid moth	3	2	2	3
Troctes divinatorius Muller	uncoun – table	uncoun – table	uncoun – table	uncoun – table

The dosage of AlP in control warehouses was 3.1g/m^3 (same as the last year) and the dosage of AlP in test warehouses was 2.26 g/m^3. In the control warehouse, cloth bags containing AlP were put on the surface of grain by workers, and the amount of AlP was divided into two portions for distribution. The AlP was distributed on the blow-holes in the test warehouses; the amount of AlP was divided into two portions for distribution. Treatment times were 40 mins for the control warehouses and 7 – 10 mins for the test warehouses. The results are shown in Table 4. The test and control warehouses were checked thoroughly after fumigation and no live pests were found in either the test or control warehouses, so the level of control was 100%.

According to the test results, several suggestions can be made:

1. Regarding the distribution of PH_3 gas in the warehouses, the method of distributing the cloth bags containing AlP on the surface of grain led to fluctuation in PH_3 concentration and poor mixing because of the time required for the AlP to react with the moisture in the air, and the interval of recirculation time. The method of distributing AlP at blow-holes resulted in the continuous recirculation of PH_3 and better penetration PH_3.
2. Regarding effectiveness against pests, although the level of control was 100%, performance of differed between the two methods. The distribution of the cloth bags containing AlP on the surface of grain needed more workers. The workers had to enter the warehouses and were exposed to the toxic gas for a long time. The distributing AlP at blow-holes improved the operation conditions of the workers.
3. Regarding the benefits, the distribution of AlP at blow-holes reduced the dosage of AlP, saved the cost of protecting the workers from the toxic gas, and protected all workers who were working in the warehouses.
4. When the two methods are compared, the treatment of the wastes resulting from distributing the AlP at blow-holes were simply and quickly after the operation of the recirculation fumigation was finished.

Table 4. Phosphine concentrations(mL/m^3) in recirculation and traditional fumigation warehouses.

Time	No. 21		No. 22		No. 5		No. 7	
	maximum	minimum	maximum	minimum	maximum	minimum	maximum	minimum
6 h	11	0	3	0	9	0	0	0
12 h	130	54	33	5	97	44	17	0
1 d	218	107	213	77	278	117	250	81
2 d	205	120	382	111	195	133	360	133
4 d	173	133	358	181	170	103	323	143
6 d	132	112	280	192	151	100	301	162
8 d	275	172	320	210	303	162	330	231
10 d	231	149	288	123	251	144	278	121
12 d	176	113	181	108	162	121	172	113
15 d	121	100	131	97	117	108	142	104

The Prevention and Treatment of Psocids Using a Combination AlP and DDVP

PH_3 gas has better penetration than DDVP but DDVP is very toxic against pests. The combination of PH_3 and DDVP in a recirculation fumigation can kill stored grain pests, including psocids which are strongly resistant to PH_3. The recirculation fumigation of combining PH_3 and DDVP can not only killpsocid adults and nymphs but also eggs which are strongly resist-

ant to insecticide. Grain has been stored safely as a result of this particular technique.

The experiment was carried out in No. 21 warehouse in the Qujing Branch of the China Grain Reserves Corporation. The rice tested was 3 952 t of Indica rice taken from another province in April 2003. Grain moisture content was 13.3%, the level of impurity was 0.9%, the maximum grain temperature was 26℃, the minimum grain temperature was 15℃, and average grain temperature 18.3℃. The pests present in the rice were *Sitophilus zeamais* (5 adults/kg), gelechiid moths (2 adults/kg), *Tribolium castaneum* (2 adults/kg), and many unidentified psocids. The insecticides applied in the test were 56% AlP tablets produced in Shandong and 80% DDVP emulsifiable produced in Shandong.

Based on the total volume of each testing warehouse and the AlP dosage of 2.26 g/m^3, 18 kg of AlP tablets (56% purity) of needed to be used; based on the total volumes of the testing warehouses and the dosage of 0.3 g/m^3 DDVP, 80% DDVP emulsifiable of 2.4 kg needed to be used. Considering the property of DDVP and the distributing way of DDVP, it was difficult for DDVP to be distributed twice. DDVP Total DDVP needed to be distributed one time before AlP was distributed. The porcelain dishes containing cotton were put on the surface of grain at intervals of 50 m^2, and total 20 porcelain dishes were put on the testing warehouse. The DDVP of 2.4 kg was distributed evenly onto the 20 porcelain dishes.

Investigation of the effect of killing pests by means of the recirculation fumigation: End of the recirculation fumigation, the air blower of axial flow was employed to ventilate after the warehouse was sealed 28 days. The samples were taken for checking the pests after the toxic gas was discharged. The samples were taken again after one month and two month. No live pests were found in any samples. The rate of control was 100%, including control of psocid eggs. Based on the results, the specific technique of the recirculation fumigation can kill all pests.

Discussion and Conclusion

Usage of the Mixture of PH_3 and DDVP

Usage of the mixture of PH_3 and DDVP does not lead to antagonism and the advantages of PH_3 and DDVP are complementary. The mixture of PH_3 and DDVP can kill the stored grain pests which can be resistant to the high level of PH_3 and the therefore the grain can be stored safely. DDVP's action includes contact toxicity, fumigant toxicity and tempting pests which are living in grain piles. DDVP is good at killing psocids and mites. The operation of recirculation fumigation using a mixture of PH_3 and DDVP has been resulted in the penetration of DDVP into grain piles, and therefore prolonging the effective time of DDVP. The aim of 100% control of stored grain pests has been achieved because of the combination of the strong penetration of PH_3 and the advantages of DDVP.

Using Ventilation Instead of Fumigation

Ventilation can inhibit the growth of psocids because it decreases the temperature and humidity in the warehouse, and psocids prefer a warm and humid environment. Therefore, the measure of ventilation can also control psocids well when there are few other pests in warehouses and the density of psocids is much small. Some psocids were found in No. 24 warehouse from April to May 2004 and were also found in the three rice warehouses from October to November 2005. The measure of ventilation was employed to treat psocids and a good result was obtained. In winter, the time of ventilation was prolonged and the conditions of low temperature and low humidity lasted a long time. At the end ventilation few psocids could be found. To meet the request of storing grain greenly and to reduce the cost of storing grain, the measure of ventilation, instead of the recirculation fumigation, can be carried out to decrease the density of psocids and to control the development of their population when the density of psocids is low.

Selection of Treatment time (Low Number of Pests) and Determination of the Measures of non-recirculation Fumigation or Postponing Recirculation Fumigation

It is very important to select the correct time to perform the recirculation fumigation in the prevention and treatment of stored grain pests. When a low number of pests are found in warehouses, the major measures should focus on an intensive checking, ventilation and decreasing grain temperature. Those measures can control the occurrence and development of pests. At the two-year cycling period of corn in our warehouses, the corn moved into the warehouse is carried out the recirculation fumigation carefully. If a low number of pests are found at some parts of the warehouse in the following year, the intensive inspection and management

will be applied. Based on the situation of pests, we need to decide whether the recirculation fumigation will be performed or not at last year. If few pests are found from the grain which needs to be delivered from the warehouses that year, the grain is not fumigated. Those operations can ensure a crop of corn to be fumigated one time in. a cycling period. At a three-year cycling period, rice and wheat will be fumigated one or two time before they are delivered from the warehouses. The rate of non-recirculation fumigation's grain is increased. If pests occur much slowly, the measure of postponing recirculation fumigation may be employed to avoid fumigating the same crop of grain repeatedly in the same year.

Application of Partial Fumigation at the Large Scale Warehouses

In the practice of fumigation in warehouses, the partial infestations of stored grain pests are frequently found in large scale warehouses when the moisture content of the grain entering warehouse is not uniform. The situation of the grain graded automatically is serious and the difference of grain temperature is big. Based on the actual situation of the partial occurrence of pests, the chemicals are put on site by means of searching tube or partial fumigation on the grain surface which is covered with polystyrene plate. Partial fumigation can reduce the amount of chemicals used, avoid fumigating all of the grain stored in warehouses and delay changes in grain quality. This specific measure can lead to the obvious economical and social benefits.

Based on the comparison test of applications of different fumigating techniques, the benefit analysis of different fumigating measures, the economic analysis of the same effects of killing pests with different methods of distribution of chemicals, applied test of combination of fumigating techniques, the effect assessment of controlling pests with non-fumigation, the influence of selecting treatment time on the fumigation and the comparison of economical benefits from the application of partial fumigation. When choosing appropriate fumigation techniques people must consider the balance of effects of killing pests and economical benefits depending on different situations. The selection of specific measures needs to consider the cycling time of grain, the season of pest occurrence, the kinds and density of pests, different fumigation methods, and the technical experience of local technicians.

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