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Study on the Control Flat Grain Beetle (*Cryptolestes ferrugineus.* Stephens) Effectively with Multi-Fumigation Technology and Multi-Pesticide

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Abstract: Taking into account pest biology and pesticide characteristics, a study was done to evaluate (1) phoshine (PH_3) fumigation with recirculation, and (2) intermittent fumigation with recirculation using PH_3 and dichlorvos (DDVP), to design the new treatment protocols for controlling *Cryptolestes ferrugineus* Stephens and *Liposcelis bostrychophila* L. The aim was not only to maximize the evenness of PH_3 distribution in the warehouse, but exploiting differences in sensitivity of the two pests to PH_3 and DDVP, thus overcoming *C. ferrugineus* and *L. bostrychophila* with strong resistance to PH_3. The results indicated that an initial PH_3 concentration of 700 mL/m^3 usually means that PH_3 concentration is maintained at 300 – 500 mL/m^3 for 16 – 25 days with resulting in an insect disinfestation rate of was 100%, with no live insects detected for 1 year afterwards. Once PH_3 concentration falls to 200 mL/m^3, PH_3 fumigation fails to control *C. ferrugineus*.

Key words: Alp, DDVP, intermittent recirculation fumigation

Introduction

Population growth of *Cryptolestes ferrugineus* Stephens can be great during grain storage, causing extreme damage and threatening stored grain security and quality of stored grain. Because phosphine fumigation was used alone for such a long time, *C. ferrugineus* has developed a strong resistance to phosphine, and it has become common and difficult to control[1,2,3]. We concluded based on our experience of stored grain pest control, that the high temperature and humidity of the southern climatic zone, and the challenge of fumigating grain bulks more than 5 m high, that recirculation fumigation, mixed fumigation, intermittent fumigation, and other methods needed to be investigated to find out more effective prevention and treatment methods. Experiments were conducted in large warehouse with (1) an intermittent application of aluminum phosphide with recirculation, and (2) fumigation a combination of aluminum phosphide (AlP) and dichlorvos (DDVP) with recirculation. With intermittent fumigation the pesticide was applied twice during the one fumigation, and the decision about when to make the second application was based on the estimated developmental stages of pests and the concentration of fumigant in the grain bulk. By splitting the application of AlP during a single fumigation, we aimed to maintain effective concentrations for long enough to disinfest grain stored under sealed conditions, by mixing phosphine fumigation with release of the volatile DDVP we aimed to exploit different degrees of sensitivity of pests to phosphine and DDVP, and by using recirculation we aimed to distribute the phosphine and DDVP evenly through the grain bulk which is usually about 5 m deep.

Experiment on the Aluminium Phosphide Recirculation Fumigation Alone

It was found in the course of fumigation in 2006, that *C. ferrugineus* was difficult to control, and common in the hot and humid areas. In April 2006, we found *C. ferrugineus* and book lice or psocids (*Liposcelis bostrychophila* L) when screening the grain bulk in one of the warehouses, so it was fumigated on the April 30 of 2006. The warehouse was made gastight when the gates, windows and van openings were sealed with PVC film. Aluminium phosphide was placed in 280 spots evenly distributed on the surface of the grain, with 1.5 m between the spots. In addition, there were 42 chinaware utensils for release of DDVP. There was 2 655 t of wheat with an average grain temperature of 21 C, and grain moisture content of 13.6%. The density of *C. ferrugineus* was 15 – 18 adults/kg and there were many *L. bostrychophila*. The aluminium phosphide (AlP) was in the form of pellets produced by Shenyang Pesticide Factory (56% purity, 1.5 kg/bottle). A total of

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31 kg of AlP was used which was equivalent to a dose of 10g/m^3. Recirculation fumigation system was used and this consisted of two single – valve air blowers (0.75 kilowatt each), a phosphine monitor, and grain thermometer.

The fumigation began on 30 April 2006 at 2:30 pm when the air temperature was 20 C. Recirculation operated at the fixed times of 8:00 – 10:00 am and 1:00 – 2:00 pm for 7 days. On 15 May 2006, the phosphine concentrations were 42, 38, 44, 21 and 30 ppm after opening the warehouse for ventillation. The density of *C. ferrugineus* was 3 – 5 adults kg and few *L. bostrychophilas* were found after sample screening. Because the AlP reaction rate was quick using recirculation fumigation, high phosphine concentrations were achieved in a short time, but effective concentrations were not maintained for long in the grain. Therefore, the level of control was bad especially in relation to eggs and the larval. This experiment showed that AlP fumigation with recirculation, is not ideal for controlling *C. ferrugineus* or *L. bostrychophilas*.

Experiment on AlP + DDVP Intermittent Mixtures and Recirculation Fumigation

Cryptolestes ferrugineus was distributed broadly but because of its feeding habits it harms only broken grain. It occurred together with the saw-toothed grain beetle (*Oryzaephilus surinamensis* (*L.*)) and Cryptolestes turcicus (Grouville). At temperatures of 32 – 35℃, its life cycle is approximately 32 days and the adults are long-lived, and these insects can reproduce deep in the grain bulks. The eggs are quite tolerant to phosphine but the adults quite sensitive to phosphine. Also, psocids are quite sensitive to DDVP. This experiment investigated control of *T. castaneum* and *L. bostrychophila* using a combination of two continuous applications of phosphine at a low dose and DDVP.

The horizontal warehouse space volume was big meaning that gas-tightness was not good. We used the intermittent and recirculation fumigation technology to make up for the insufficient gas-tightness, and maintain the concentrations long enough to be lethal to insects. The first dose aimed kill the sensitive insect stages (larvae and adults), and the second dose after 6 – 10 days, aimed to kill larvae and adults that had developed from eggs and pupae that survived the first dose.

The experiment was conducted in the same storehouse as the first experiment. The storehouse was a horizontal warehouse constructed in 1988 (35 m long × 17.5 m wide) and the grain bulk was 5.3 m high with a volume of 3 246 m^3. There was 2 655 t of wheat with an average grain temperature 20.3 – 25.3℃ and moisture content of 13.6%. Under these conditions the luster and smell of the wheat is normal, and there is no condensation, molding or spoilage. The density of *C. ferrugineus* was 20 – 30 insects/kg. storage. The AlP was in the form of pellets produced by Shenyang Pesticide Factory (56% purity, 1.5 kg/bottle). In addition, DDVP and malathion were used. The recirculation fumigation system included a PVC gas pipeline (0.14 mm thickness), organized like the Chinese word "非" tape, and connected with the fumigation dead angle of grain bulks. The main pipe was 80 cm diameter, and the branches were 55 cm diameter. There were two single-valve air blowers (0.75 kilowatts each), a phosphine gas monitor and grain thermometer. The Alp dose was 9 g/m^3 or a total of 18 kg, plus a total of 20 bottles of DDVP (330 g each) and four bottles of malathion (1 kg each) for space disinfestations.

The first fumigation started on 24 October 2006, and the Alp dose was 6 g/m^3 or a total of 12 kg, and two insect sample bags had been installed on the grain surface and 30 cm bellow the grain surface. Each bag contained 36 *C. ferrugineus* and 12 maize weevils (*Sitophilus zeamais* (Motschulsky)). Fumigation method: The Alp was uniformly distributed over the grain surface in 294 spots securely in cloth bags, in air pipes in the grain bulk. (The idea was for the DDVP and phosphine to be mixed through the recirculation fumigation, therefore increasing the poisonous effect of the treatment.) Because the volatility of DDVP is high, the stomach poisonous function was obvious, but longevity of the residue is short, therefore it was sprayed to gunny bags directly, with the aim of maintaining a high concentration for a short time. Recirculation began the next day for the fixed periods of 8:00 – 10:00 am and 1:00 – 2:00 pm each day. Based on the phosphine concentrations measured, and the evenness of concentrations through the grain bulk, the recirculation was stopped after 7 days.

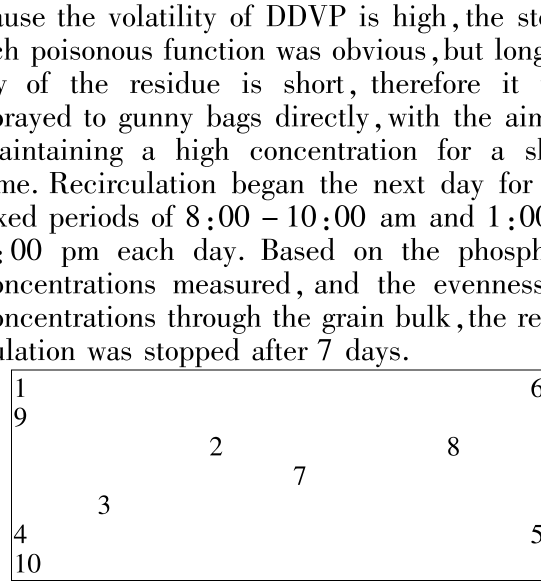

Fig. 1 Gas cxamination site plan

PH_3 Density examination method: On latter 12 hours after puts the insecticide, then start to examine the PH_3 density, afterward every day examines 1 time before starting the circulating fan, until the density drops to below 100ppm, then stop the examination.

On 7 November 2006 the warehouse was opened for pest inspection, and there were no live insects outside the grain bulks, but in the grain bulks there were 2 insects/kg. The second time fumigation started on the morning of 8 November 2006, with a dose of AlP of 3 g/m^3 or a total of 6 kg, together with 8 bottles of DDVP using the same methods used in the first fumigation. The phosphine gas concentration changed during the fumigation at the different sampling points (Table 1).

Table 1. Phosphine concentrations measured during fumigation.

Point Detection Date	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
10.25	1 210	880	270	1 209	460	520	440	510	740	1 207
10.26	1 211	930	1 207	728	1 206	1 145	1 208	1 206	914	696
10.27	1 267	1 212	1 264	1 074	1 264	1 265	1 266	1 265	1 266	680
10.28	1 266	600	1 264	984	1 266	1 266	1 266	1 266	1 224	680
10.29	1 103	617	1 263	1 100	1 265	1 269	1 263	1 264	1 265	847
10.30	1 043	354	1 266	926	1 266	1 268	1 266	1 266	822	960
10.31	1 051	365	1 266	931	1 266	1 268	1 266	1 266	1 266	915
11.1	900	143	1263	960	1 266	1 266	1 266	1 266	1 056	804
11.2	689	118	950	750	986	1 037	1 055	889	883	721
11.3	432	56	428	396	523	453	432	406	382	343
11.4	121	41	96	108	56	38	77	81	80	38
Second time										
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
11.11	895	905	876	964	1010	692	986	892	932	896
11.12	895	935	915	976	982	715	895	826	930	896
11.13	580	425	500	550	530	413	440	800	520	502
11.14	570	401	408	551	520	409	410	460	501	502
11.15	508	402	395	500	505	481	396	390	407	501
11.16	440	231	860	366	493	771	456	560	400	405
11.17	263	180	303	181	296	283	181	203	109	181

Note: In the grain bulks has not buried the PH_3 examination drive pipe, measured that the density is the grain bulks the surface layer (only to reference) the unit: ppm

The warehouse was opened on 17 November 2006 for ventilation and pest screening on 20 November 2006 confirmed 100% disinfestation. Routine weekly inspection for 1 year failed to discover any live pests, confirming control of phosphine resistant T. castaneum and other pests.

Analysis and Discussion

1. The use of intermittent applications together with recirculation may be a way to obtain better levels of control of *C. ferrugineus* and *L. bostrychophila*.
2. In order to control grain pests, instead of simply increasing the AlP dose, the level of gastightness should be increased as much as possible, to guarantee effective concentrations for longer. If the phosphine concentration is excessively high then it may cause *C. ferrugineus* to enter a protective stupor, making the achievement of ideal control difficult.
3. When controlling *C. ferrugineus*, the goal should be to achieve an initial concentration in the grain bulks of 700 mL/m^3, to maintain concentrations above 300 – 500 mL/m^3 for generally 16 – 25 days. Only then is it possible to achieve the ideal fumigation against *C. ferrugineus*. When the concentration drops below 200 mL/m^3 the fumigation will fail.

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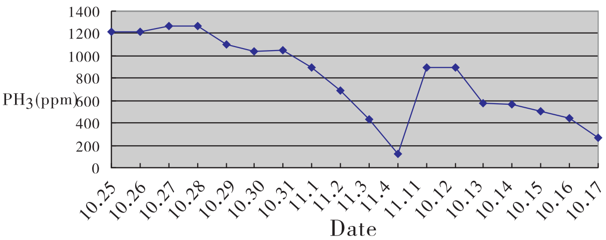
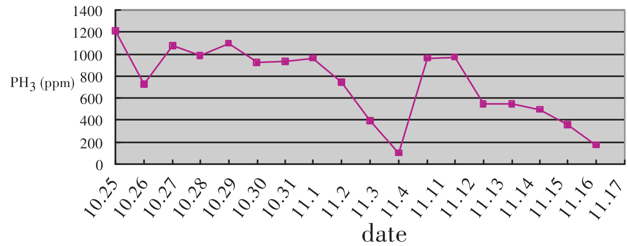
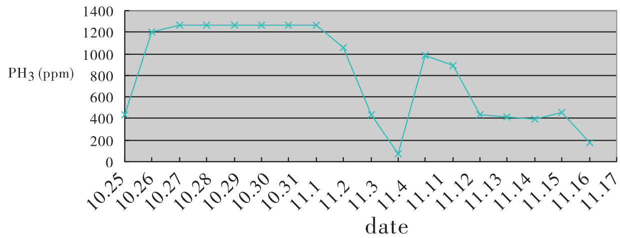


No. 2. PH_3 density change table



No. 3. PH_3 density change table



No. 4. PH_3 density change table