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A Field Trial of Phosphine Fumigation on a High Resistant Strain of Rusty Grain Beetle in Paddy Rice Stored in Horizontal Storage

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Abstract: A phosphine fumigation trial was conducted on bulk paddy rice stored in a horizontal warehouse (10. 19. 13. 8 m). The rice was covered with clear PVC sheeting (0. 14 mm thick) that was sealed to the walls by pushing it into a slot with a rubber pipe. Phosphine was applied as aluminium phosphide three times during the fumigation at application rates of 6, 3 and 1 g/m^3 of tablets. The aim was to determine the suitability of the storage for fumigation and the application rate needed to control very highly resistant *Cryptolestes ferrugineus*. Cages of highly resistant (x328) and susceptible *Rhyzopertha dominica* and a strain of *C. ferrugineus* collected from the paddy were placed under the sheeting at the beginning of the fumigation. Phosphine concentration was monitored during the fumigation. Despite gas leakage due to the poor condition of the warehouse, phosphine concentration was maintained at > 200 mL m^{-3} for more than 35 days. Insect cultures could be clearly observed through the covered plastic sheeting during the fumigation. There were no active adults of susceptible or resistant *R. dominica* after 3 and 15 days, respectively. However, *C. ferrugineus* adults could be observed moving in the cages until day 30. No insects were present in the grain six months later when the sheeting was removed. The results indicate that very highly resistant strains can be controlled if a sufficient concentration of phosphine is maintained for along enough exposure period. The appropriate exposure period can be accurately determined by observing the response of the insects infesting the grain mass.

Key words: phosphine fumigation, rusty grain beetle, exposure time

Introduction

In local grain storages in southern China, paddy is usually stored in bulk or in bag stacks in warehouses that are not suitable for phosphine fumigation due to poor gas – tightness. However, insect pest infestation is always a serious problem in this region due to the warm, moist climate and the grain is often fumigated with phosphine (tablets of aluminium phosphide) as there is no other practical means of control. Under these conditions, there are usually some survivals of insect pests and resistance to phosphine has developed so that control failures have become more and more common, especially in some species or populations of insect pests. The Rusty grain beetle, *Cryptolestes ferrugineus*, has become a serious pest because it is now the most difficult species to control with phosphine.

Herein, we describe a field trail that was carried out on bulk paddy rice stored in a horizontal warehouse where the rice was covered with clear PVC sheeting that was sealed to the walls by pushing it into a slot with a rubber pipe. Phosphine was applied as aluminium phosphide three times during the fumigation. The aim was to determine the suitability of the storage for fumigation and the application rate needed to control very highly resistant *Cryptolestes ferrugineus*.

1 Materials and Methods

The trial was conducted on bulk paddy rice of 193 tonne stored in a horizontal warehouse (10. 19. 13. 8 m) in Minzhong Grain Depot, Zhongshan, Guangdong Province, China. The rice was covered on top with clear PVC sheeting (0. 14 mm thick) that was sealed to the walls by pushing it into a slot with a rubber pipe. The moisture content of rice was 12. 7%. Insect infestation was 12 adult insects per kilogram, including rice weevil (*Sitophilus oryzae*), lesser grain borer (*R. dominica*) and rusty grain beetle (*C. ferrugineus*) in the paddy. The temperature of paddy rice was 20 – 26℃ and ambient conditions in the warehouse were 26 – 32℃ and 70% – 90% relative humidity.

New PVC sheeting was used and checked against daylight for holes before use. Any holes were sealed with glue. Sheets were joined to each other by overlaping them about 40 mm and

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heat sealing.

The bag-stack was tested for gas-tightness by applying a negative pressure. A vacuum hose was inserted through the plastic sheeting and air withdrawn. Only 80 Pa of highest negative pressure was read from a water-filled manometer. The gas-tightness was not high enough for a single application of fumigant, so second and third supplements were carried out to ensure an effective concentration during the fumigation period.

Four groups of insect cages of highly resistant (x328) and susceptible *Rhyzopertha dominica* and a strain of *C. ferrugineus* collected from the paddy were placed under the sheeting at the beginning of the fumigation. The cages consisted of 50 adults insects, in culture medium, contained in glass tubes (70 mm long × 10 mm diameter) covered at each end with gauze to allow free flow of gases. Several tubes were glued into the sheets to facilitate insect checking and tablet application.

Phosphine was applied as aluminium phosphide three times during the fumigation at application rates of 6, 3 and 1 g/m^3. The tablets were put in cotton bag (10 cm × 8 cm, 150 g aluminium phosphide per bag) and inserted into the grain mass 20 – 30 cm in depth through the PVC sheeting, which was sealed after the application. The second and third applications were decided according to the phosphine concentration motored in progress. Nylon tubing for gas sampling, 3 mm inner diameter was inserted through small holes into the sheeting at four points (Figure 1). Phosphine concentration was measured at intervals of 24 hours (at 11.00 am each day), using an electronic monitor (model HL – 210, Xinjialiang Co., Beijing, P. R. China) with a range of 0 – 1000 mL/m^3, and phosphine detection tubes (ALARM brand, Hebi Gas Detecting Tube Manufacture, Hebi, Henan Province). Phosphine concentration was measured in units of mL/m^3 (ppm).

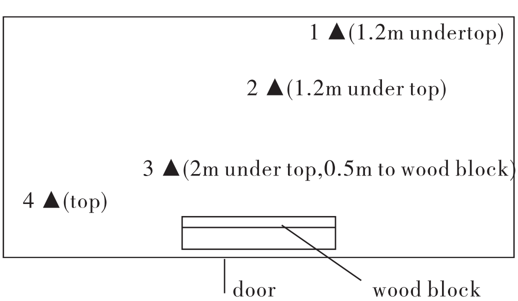

Fig. 1 Sketch of gas sampling for phosphine monitoring

2 Results

Phosphine concentration of four monitoring points is shown as Table1 and Figure2.

Table1. Phosphine concentration of four monitoring points (mL/m^3)

date	time (d)	Point1	Point2	Point3	Point4
April. 15	1	51	108	414	22
April. 16	2	176	384	540	59
April. 17	3	386	510	725	173
April. 20	6	570	950	985	320
April. 22	8	875	902	1200	306
April. 24	10	915	820	945	234
April. 27	13	776	608	656	194
April. 29	15	636	528	512	185
April. 30	16	520	468	382	152
May. 2	18	657	398	724	228
May. 3	19	766	380	846	344
May. 6	22	768	344	662	334
May. 7	23	685	454	572	170
May. 8	24	617	482	532	346
May. 9	25	612	466	556	388
May. 12	28	610	378	658	405
May. 13	29	610	354	622	395
May. 14	30	582	326	505	444
May. 15	31	548	308	451	370
May. 19	35	286	206	328	58

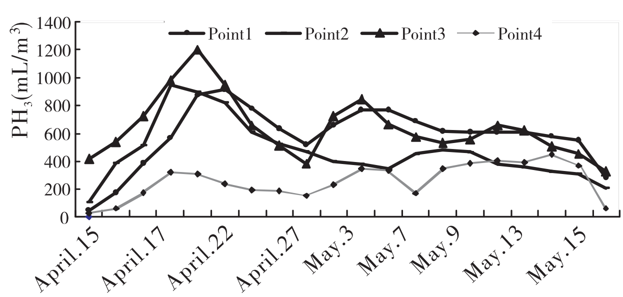

Fig. 2 Phosphine concentration of four monitoring points

Our results (Table 1 and Fig. 2) indicate that phosphine concentration reached a higher level on the second day after tablet application. The peak concentration occurred in about eight days. When the concentration at point 4 was less than 200 mL/m^3, the second 3 g/m^3 of tablets was added. Again, the third application (another 1 g/m^3 of tablets) was carried out when phosphine concentration began to decrease. The lower the dosage of tablets used, the lower the peak concentration monitored. Among four monitored points for phosphine, point 4 always gave lowest concentration due to a fine slot existed on the wall near the point. Despite gas leakage due to the poor condition of the warehouse, phosphine concentration was maintained at >200 mL/m^3 for more than 35 days.

There were no active adults of susceptible or resistant *R. dominica* after 3 and 15 days, respectively. However, *C. ferrugineus* adults could be observed moving in the cages until day 30. There were no survivals in the culture sampled from grain mass and cages after 14 days. No insects were present in the grain ten months later when the sheeting was removed. The results indicate that very highly resistant strains can be controlled if a sufficient concentration of phosphine is maintained for a long enough exposure period. The appropriate exposure period can be accurately determined by observing the response of the insects infesting the grain mass.

3 Disscussion

The purpose of this work was to determine if a leaky warehouse could maintain phosphine concentrations long enough and at high enough concentrations to control resistant insects by supplementing phosphine dosing. Complete control of both the test insects and the natural infestations suggest that the fumigations may be successful against resistant strains prevalent in China. A weakness with this trial was that the test insect samples contained adult insects and probably some eggs and we have no evidence of other stages being present. However, further culture of insects in cages and samples from grain mass indicate that the trial methodology was successful in achieving complete control of the test resistant insects.

Several authors have characterised high resistance in *R. dominica* and Dr. Collins has summarised their results at doses measured in these trials. At 0.2, 0.3, 0.5 and 0.7 g/m^3, 10, (Collins et al. 2005), 8 (Collins et al. 2005, Rajendran and Gunasekaran 2002), 6 – >9, (Collins et al. 2005, Liang et al., Price and Mills 1988) and >7 (Sayaboc et al. 1998, Rajendran and Gunasekaran 2002) days are required for complete control, respectively. Fewer data are available for resistant strains of other species. Resistant *S. oryzae* populations can be very difficult to control: all life stages of a strain from Bangladesh were controlled in 10 days at 0.47 g/m^3 (Price and Mills 1988), and a resistant strain from Australia was controlled in 10, 7 and 5 days at 0.3, 0.5 and 0.7 g/m^3 (Daglish et al. 2002), respectively, while Nayak et al. (2003) report that it took 11 days to control a resistant strain from China at 0.3 g/m^3. Price and Mills (1988) achieved 98.8% control of resistant *C. ferrugineus* at 0.47 g/m^3 in 10 days. *L. entomophila* requires 7 days at 0.3 g/m^3 (Nayak et al. 2003) or 9 days at 0.27 g/m^3 Pike (1994) for complete control. Therefore, based on theworst – case' of published reports, phosphine doses required to control all documented resistant strains are: 0.2 g/m^3 for >10 days, 0.3 g/m^3 for 10 days, 0.5 g/m^3 for 10 and 0.7 g/m^3 for >7 days. This trial provided that a high enough concentration for long enough is indeed necessary to successfully control higher level of resistant strains, especially for rusty grain beetle.

In conclusion, insects with different levels of resistance to phosphine require different concentration and exposure times for complete control. An extraordinarily long time with higher concentration is necessary for successful fumigation of some insects resistant to phosphine such as rusty grain beetle. During fumigation, supplementary application of phosphine is a useful approach to maintain effectiveconcentration in a leaky warehouse.

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References

[1] Bell C. H., B. D. Hole and P. H. Evans (1977): The occurrence of resistance to phosphine in adult and egg stages of strains of Rhyzopertha dominica (F.) (Coleoptera: Bostrichidae). 13, 91 – 94

[2] Collins, P. J., Daglish, G. J., Pavic, H. and Kopittke, R. A. (2005). Response of mixed – age cultures of phosphine – resistant and susceptible strains of lesser grain borer, Rhyzopertha dominica, to phosphine at a range of concentrations and exposure periods. Journal of Stored Products Research 41: 373 – 385

[3] Daglish, G. J., P. J. Collins, H. Pavic and R. A. Kopittke (2002): Effects of time and concentration on mortality of phosphine – resistant Sitophilus oryzae (L) fumigated with phosphine. Pest Manag. Sci., 58, 1015 – 1021

[4] Hole B. D., C. H. Bell, K. A. Mills and Gwen Goodship (1976): The toxicity of phosphine to all developmental stages of thirteen species of stored product beetles. 12, 235 – 244

[5] Howe R. W. (1973) The susceptibility of the immature and adult stages of Sitophilus granarius to phosphine 8,241 – 262

[6] Nakakita H. and R. G. Winks (1981): Phosphine resistance in immature stages of a laboratory selected strain of Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). 17,43 – 52

[7] Nayak, M. K., P. P. J. Collins, H. Pavic (2002): Resistance to phosphine in psocids: challenges ahead! In Stored Grain in Australia 2000, Proceedings of the Australian Postharvest Technical Conference, Adelaide, 1 – 4 August 2000 (Ed. E. J. Wright, H. J Banks and E. Highley), CSIRO. Canberra, Austalia, P. 113 – 118

[8] Pike, V (1994): Laboratory assessment of the efficacy of phosphine and methyl bromide fumigation against all life stages of Liposcelis entomophilus (Enderlein). Crop Protection, 13, 141 – 145

[9] Price L. A. and K. A. Mills (1988): The toxicity of phosphine to the immature stages of resistant and susceptible strains of some common stored product beetles, and implications for their control. 24,51 – 59

[10] Rajendran S. and N. Muralidharan (2001): Performance of phosphine in fumigation of bagged paddy rice in indoor and outdoor stores. 37,351 – 358

[11] Wang D., Z. Qin and W. Song (2002): LS/T1201 – 2002 Fumigation Regulation of Phosphine Recirculation, The Standard of State Administration of Grain, Standard Publishing House of China, Beijing

[12] Winks R. G. (1984) The toxicity of phosphine to adults of Tribolium castaneum (Herbst): Time as a dosage factor.. 20,45 – 56

[13] Winks R. G. and C. J. Waterford (1986): The relationship between concentration and time in the toxicity of phosphine to adults of a resistant strain of Tribolium castaneum (Herbst). 22,85 – 92