

Effective control of resistant rusty grain beetle during commercial fumigation of corn using VAPORPH₃OS[®] phosphine fumigant in Isabela Philippines

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Abstract

The corn industry in the Philippines has been experiencing a serious insect infestation problem with strong resistant rusty grain beetle (*Cryptolestes ferrugineus*) which cannot be completely controlled by the current fumigation practice of aluminium phosphide tablets. This was brought about by the strong resistance to phosphine developed by rusty grain beetle over decades of poor fumigation practices using aluminum phosphide tablets. The corn traders and handlers particularly in the province of Isabela Philippines have suffered significant losses in quantity and quality of the corn stored as well as monetary losses due to rejection of corn delivery to customers. In response to this problem, CYTEC and Sterix Inc. introduced new fumigation protocols and procedures using VAPORPH₃OS[®] phosphine fumigant. VAPORPH₃OS[®] (99.3% phosphine w/w) is a cylinderized phosphine product which is commercially used globally for safe, effective and user-friendly fumigation of food and non-food commodities. VAPORPH₃OS[®] is dispensed in any fumigation structure using a fumigation machine which blends pure phosphine and ambient air to deliver a non-flammable mixture. A dose of 800 ppm minimum concentration for 7 days during summer months at 28 - 33°C and 1,000 ppm for 11 days during rainy months at 23 – 27°C have proved to be 100% effective in killing all stages of resistant rusty grain beetle. This paper describes the development and commercial application of the high dose and long exposure time protocol using VAPORPH₃OS[®] for corn fumigation in tarpaulin covered bag stacks in Isabela Philippines. The value added benefits of using VAPORPH₃OS[®] include the excellent control of strong resistant rusty grain beetle, zero rejection of corn deliveries to customers, maximization of storage and transport services, guaranteed high quality of stored grain, safer and more efficient storage operation and good reputation from the customers.

Keywords: VAPORPH₃OS[®], phosphine fumigant, strong resistant rusty grain beetle, commercial corn fumigation, fumigation protocols, Horn Diluphos System

1. Introduction

Corn is the second largest crop produced in the Philippines. In 2013, about 8.2 million tons of corn was harvested with Isabela as the top producing province at 1.6 million tons or 20% of the total production in the country. Isabela has immense flat and rolling terrain and sufficient rainfall which makes it suitable for crop production. Yellow corn is a primary ingredient of animal feeds and accounts for 50% of the livestock mixed feeds (Philippine Department of Agriculture, 2013). This production of animal feeds requires corn to be stored for several months to sustain the continuing supply to the feed processors for the production of feeds.

As corn is stored at the production sites for a longer period (3- 6 months or more), insect infestation has become a common and serious problem. The common practice of storing corn is in 50-kg bags and stacked in rectangular fashion up to 25 layers of bags inside a warehouse (Figure 1). Rusty grain beetle (*Cryptolestes ferrugineus* and commonly called flat grain beetle)

is the major insect pest that damage corn during storage. Aluminium phosphide tablets were the commonly used fumigant for controlling rusty grain beetle in Isabela in the last 30 years. The bagged corn stocks are covered with tarpaulin enclosure and sealed with sand snakes at the bottom during fumigation (see Figure 2). The use of tablets however, is not effective anymore to completely control the rusty grain beetle infestation to stored corn in Isabela and other corn production areas in the country.

The corn traders particularly in the province of Isabela Philippines are the ones who handle and store corn before they deliver it as raw material to the feed processors. Due to ineffectiveness of aluminum phosphide tablets to completely control strong resistant rusty grain beetle, they have suffered significant losses in quantity and quality of the corn stored as well as rejection of delivery to customers. In response to the above problem, CYTEC and Sterix Inc. introduced new phosphine fumigation protocols and procedures using VAPORPH₃OS[®] phosphine fumigant as effective alternative solution to the strong resistance issue of rusty grain beetle. VAPORPH₃OS[®] (99.3% phosphine w/w) is a cylinderized phosphine gas product which is commercially used globally for safe, effective and user-friendly fumigation of food and non-food commodities. VAPORPH₃OS[®] is dispensed in any fumigation structure using a suitable fumigation machine (e.g. Horn Diluphos System - HDS) which safely blends pure phosphine and ambient air to deliver a non-flammable mixture. A non-flammable mixture of 10,000 ppm of phosphine in air is released from the HDS and delivered into the fumigation structure.

2. Factors in Phosphine Resistance Development

Phosphine from aluminum phosphide tablets has been used in Isabela and other corn production areas in the Philippines in the control of all insects infesting corn for the past three decades. However, the prolonged use of the same phosphine fumigant at the same dose, favorable weather conditions (high humidity and temperature) during storage and poor fumigation practices have led to the development of strong resistance to phosphine of rusty grain beetle. Rusty grain beetle has by far the highest level of resistance to phosphine among major grain insect pests. Rusty grain beetle is four times more tolerant to phosphine than the other common strong resistant insects such as the lesser grain borer (*Rhyzopertha dominica*) and rice/corn weevils (*Sitophilus* spp.).

On the aspect of poor fumigation practices, the major contributors to development of phosphine resistance are below (Tumaming, 2013).

1. The main cause is the lack of strict adherence to the fumigation protocols (minimum phosphine concentration, exposure time at a given temperature) leading to sub-lethal dose that enable some insect population to survive.
2. Inadequate sealing and maintenance of the fumigation structure leading to excessive gas loss and under dosing.
3. Lack of regular monitoring of phosphine concentration.
4. Inability to top up of phosphine concentration to maintain minimum target concentration.
5. Lack of good hygiene and sanitation to reduce multiplication of resistant insects and prevent re-infestation of fumigated commodities.
6. Lack of monitoring of insect survival to determine resistance.
7. Assumption that once aluminum phosphide tablets are placed inside the fumigation structure it will do the killing of all insects automatically.

3. Impact of Survival of Strong Resistant *C. ferrugineus*

One of the biggest corn traders in Isabela was used as a case study to assess the impact of the phosphine resistance issue on its business operation. With insect survivors from rusty grain beetle, the corn feed companies that received the delivered corn adopted strict quality control and rejected up to 40% of the deliveries. The rejection of corn deliveries resulted in direct monetary losses from return of delivery trucks and corn to Isabela, double the handling expenses, repeat fumigation expenses and lower corn quality. There were also indirect monetary losses due to damaged supplier reputation from non-compliance to customer quality requirements and potential loss of business to unsatisfied large customers.

4. Proposed Effective Solution to Phosphine Resistance

In response to the serious strong resistance issue with rusty grain beetle, Cytec and Sterix Inc. (Cytec local distributor in the Philippines) collaborated to analyse the resistance issue and propose an effective solution. The first step under taken to address the strong resistance to phosphine of rusty grain beetle is the development of appropriate fumigation protocols. The results of efficacy studies of phosphine against strong resistant rusty grain beetle in Australia developed by Nayak et al (2013) for Cytec were used as reference to establish the suitable fumigation protocols for corn in the Philippines. Small scale tarpaulin fumigation trials of corn using ECO₂FUME[®], a 2% phosphine formulation in CO₂ manufactured by CYTEC, were conducted on rusty grain beetle infested corn to select and validate the effective fumigation protocols. The phosphine fumigation protocols found to be effective control of strong resistant rusty grain beetle are below.

1. 800 ppm minimum phosphine concentration for 7 days at during summer months (28 - 33°C).
2. 1000 ppm minimum phosphine concentration for 11 days during rainy months (23 – 27°C) with relative humidity of >85%.

The higher concentration and longer exposure time protocol during rainy months is needed due to lower temperature and higher relative humidity which have direct effect on reducing the rate of phosphine uptake by the insect.

During the commercial application for bagged corn in tarpaulin fumigation sheet, VAPORPH₃OS[®] was used as a more cost effective approach. VAPORPH₃OS[®] is dispensed with the use of an HDS 200 fumigation machine with phosphine discharge rate of 3 kg/hr. Figure 3 shows the setup of gas distribution pipe and HDS 200 hose connection to distribute the phosphine gas safely and evenly inside the tarpaulin enclosure.

Aside from using VAPORPH₃OS[®], other best fumigation practices were employed as below.

1. Pre-inspection of facilities
2. Hygiene and sanitation inside and outside of the warehouse
3. Replacement with new tarpaulin plastic sheet to ensure there are no cracks as potential source of gas leaks
4. Use of packaging tapes and cement glue for better sealing of the tarpaulin sheet
5. Gas monitoring twice a day to keep track of gas concentration and maintained at minimum concentration

5. Comparison of Cylinderized Phosphine Gas and Aluminum Phosphide Tablets

Table 1 shows the comparative features of cylinderized phosphine gas (ECO₂FUME[®], VAPORPH₃OS[®]) and aluminum phosphide tablets. When it comes to controlling phosphine resistant insects, the use of cylinderized phosphine gas is more advantageous due to its ability to achieve higher phosphine concentration quickly and maintain it for a longer exposure time needed to kill all stages of insects.

Table 1 Comparison of features of cylinderized phosphine gas and aluminium phosphide tablets.

Cylinderized Phosphine Gas	Aluminum Phosphide Tablets
Excellent control of phosphine levels.	Minimal (if any) control of phosphine levels and wide variation in phosphine concentration during the fumigation period.
Can maintain constant phosphine level & reduced phosphine amount vs. tablets to achieve the same efficacy.	Cannot maintain constant phosphine level leading to incomplete kill of all stages of insects.
Reaches desired phosphine level quickly	Need up to 24 hours to reach desired level
Efficient & more reliable fumigation process	Labor intensive fumigation process Risk of failure due to insect narcosis
No direct contact with the product	Manual handling of tablets before and after the fumigation
Safe & easy to handle	Risk of fire and explosion
No waste product to dispose of (environment-friendly)	Spent tablets needs to be recovered and disposed of they still represent a hazard
Ideal for any combination of concentration x exposure protocol	Cannot maintain a phosphine level above 500 ppm for a long period, topping up is impractical or impossible
No residual phosphine on commodity.	Can leave residual metal phosphide or oxide on the product

6. Value Added Benefits of Cylinderized Phosphine Gas

The use of VAPORPH₃OS[®] offered value added benefits to the corn traders and handlers in Isabela Philippines as below which led to the conversion from aluminum phosphide tablets.

1. 100% mortality of strong resistant rusty grain beetles in fumigated corn.
2. Surge in insect activity (3 O'clock habit) of rusty grain beetles in the warehouse facilities has disappeared.
3. Corn powder residues from insect activity are much lower.
4. Damaged kernels have become virtually undetectable (Figure 4).
5. Overall corn quality has improved resulting in higher value of commodity
6. Trucking and hauling services optimized.
7. Overall improvement of the working environment
8. No repeat fumigation
9. Zero rejection of corn deliveries to feed processors

10. Gained high reputation for supplying high quality corn as raw material for feeds

7. Impact of VAPORPH₃OS[®]/HDS technology to Sterix and Fumigation Practices for Corn

The first Isabela corn trader customer of Sterix which originally use aluminum phosphide tablets has converted to VAPORPH₃OS[®] for fumigation of all its 9 warehouses with a total volume of 45,000 m³ of corn bag stocks. As a result of the success story in the use of VAPORPH₃OS[®] in one on the corn traders in Isabela, other corn traders have contacted Sterix and converted from aluminum phosphide tablets to VAPORPH₃OS[®]. Sterix fumigation service business has grown 13 times over for Isabela corn traders. The success of STERIX is now expanding to other feed mills in the Philippines, with a unique solution to control strong resistant strain of rusty grain beetle using VAPORPH₃OS[®] and coupled with adoption of integrated pest management for complete insect pest management of corn storage facilities.

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Figure 1 Typical warehouse for bagged corn storage of corn traders in Isabela Philippines.



Figure 2 Setup of tarpaulin covered bag stock during fumigation with tablets.

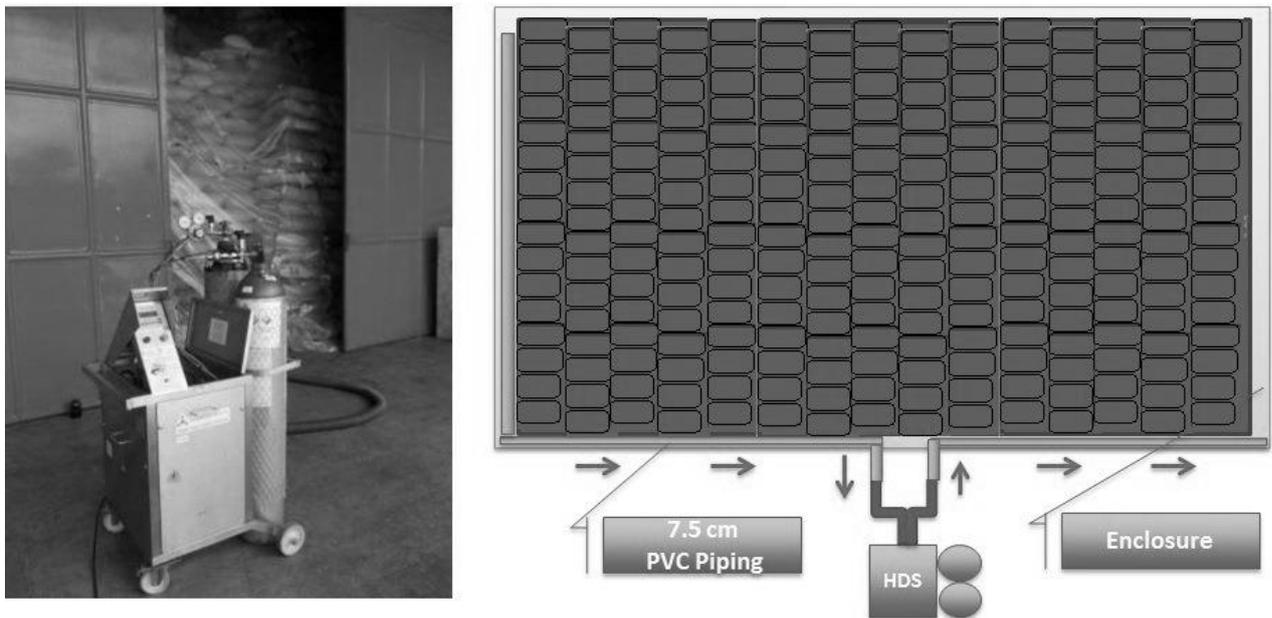


Figure 3 Setup and layout of the HDS 200 and PVC pipe inside the tarpaulin enclosure to safer and uniform phosphine gas distribution.

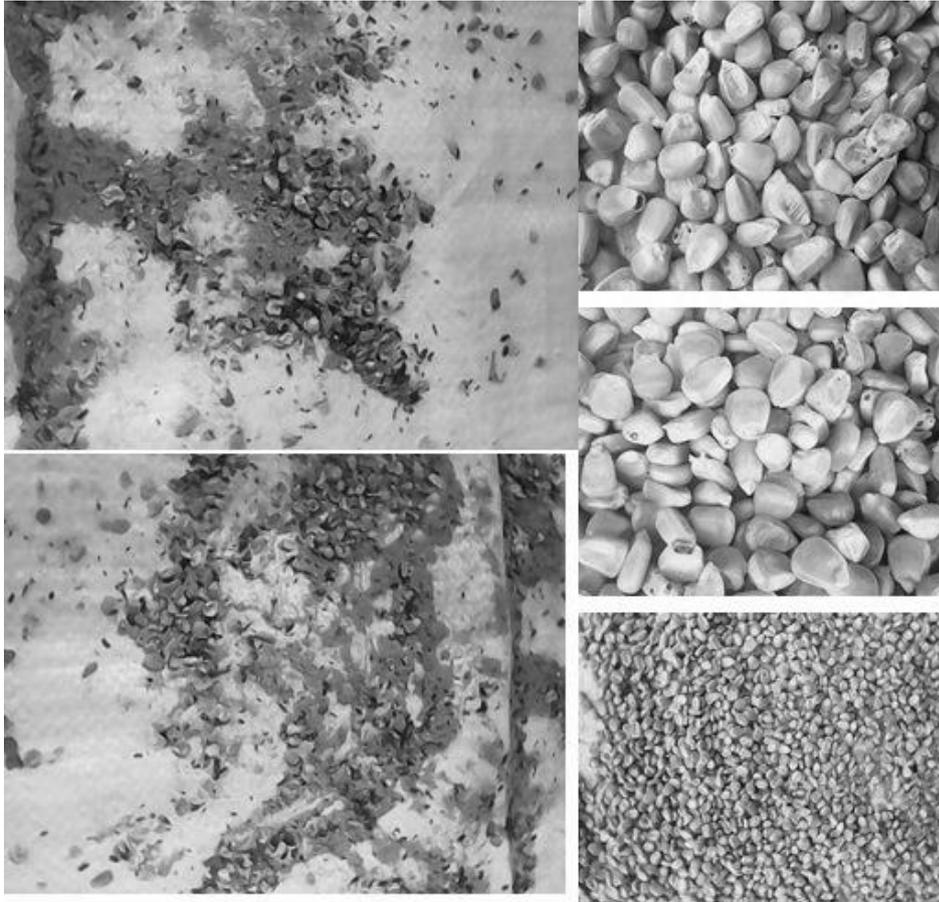


Figure 4 Comparison of insect infested and damaged corn from previous practice with tablets (left side photos) and insect free corn fumigated with VAPORPH₃OS[®] (right side photos).

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