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AN EXPERIMENTAL PROCEDURE TO ERADICATE STRONG PHOSPHINE RESISTANT GRAIN INSECTS FROM UNSEALED STEEL SILOS USING ETHYL FORMATE

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ABSTRACT

Western Australia (WA) relies on phosphine at export to meet the regulated nil tolerance standards for exported grain. Phosphine fumigation is also the main insect control method used on farms in WA. To protect the export market it is important to limit the development of phosphine resistance. To create a gas tight enclosure for a successful fumigation of unsealed silos involves covering them with gas proof sheeting. To reduce the cost of sheeted fumigation a technique of recirculating ethyl formate was used effectively in an unsealed silo on a farm in the mid northern wheat belt of WA to control a strong resistant strain of *Tribolium castaneum*. The technique and bioassay results are discussed.

Key words: *Tribolium castaneum*, *Rhyzopertha dominica*, *Sitophilus oryzae*, *Trogoderma variable*, grain fumigation

INTRODUCTION

Phosphine resistance has become a major problem in many parts of the world. In Western Australia (WA) a phosphine resistance monitoring and management program on across farm and central storage enables collection of samples of grain insects for testing to determine resistance status. When a strong resistance is detected on a farm an eradication plan is activated and for this to be successful all parcels of grain must be treated. Eradication can be achieved in sealable silos which enable efficient control, holding phosphine at a higher dose for a longer exposure period, but unsealed silos on many farms are unable to retain the gas long enough to control all life stages of the insect. To create a gas tight enclosure for a successful fumigation involves covering the unsealed silo with gas proof sheeting. The farm selected for this experimental treatment contained a strong resistant strain of *Tribolium castaneum* (Herbst) created by many years of poor quality fumigations in unsealed silos.

MATERIALS AND METHODS

The 51.5 m³ capacity unsealed steel silo selected for the fumigation trial with Ethyl Formate (EF) was prepared by installing a 90 mm PVC flange on the roof and taping a steel plate with a 90 mm steel flange to the lower grain outlet. A 90 mm i.d. PVC drainage hose was connected from the lower outlet to a fan and then to the headspace (Fig. 1). Bioassays of laboratory reared cultures containing all life stages of *Rhyzopertha dominica* (Fabricius), *Sitophilus oryzae* (Linnaeus), *Tribolium castaneum* and *Trogoderma variable* (Ballion) larvae were probed 0.5m into grain in the headspace and placed in the lower silo outlet. Liquid EF at a dose rate of 160g per t was poured onto the top of 50 t of wheat in the silo (Fig. 2). Grain temperature was 25-28°C. The fan was activated drawing the air/EF mixture from the bottom of silo and blowing it into the headspace at a rate of 122 m³/h for 2 h providing 2.4 internal air exchanges/h.

A control group of mixed age insect cultures were established under the same incubation conditions with the treatment group before fumigation and seven-week post-fumigation. The bioassay comparison of weekly counting of insect adults between the treatments and the controls provided the confidence of fumigation efficacy for all life stages.



Fig. 1- Fan connected to base and headspace of silo by a 90mm i.d. flexible pipe.

RESULTS

After recirculation the concentration of EF as measured on site with a gas chromatograph was evenly distributed through the silo and the recirculation fan was turned off. The concentration \times time (*Ct*) product is shown in Table 1 and the inter-granular concentration decay in Fig. 3. The bioassays were retrieved from the base of the silo after 24 h and from the headspace after seven days.

All insects retrieved from the base of the silo were found to be dead. The bioassays retrieved from 0.5 m from the grain peak showed 100% mortality of all life stages of *R. dominica*, and *S. oryzae*, and 100% mortality of *T. castaneum* adults and *T. variable* larvae. Three *T. castaneum* adults emerged at week 6 after fumigation, indicating some egg survival.



Fig. 2- Pouring liquid Ethyl Formate into the top of the silo.

The control bioassay on *R. dominica*, *S. oryzae*, and *T. castaneum* mixed age cultures in seven-week incubation after fumigation gave the reference population sizes in all stages to the fumigated cultures. This is demonstrated by the existing adult numbers (n) at week 0, and the total new emerging adults numbers from week 1 to 6: (123) 689 *R. dominica*, (893) 2047 *S. oryzae* and (356)185 *T. castaneum* adults. 217 *T.variable* larvae were removed from the control in week 0 and no further larvae developed from week 1 to week 6.

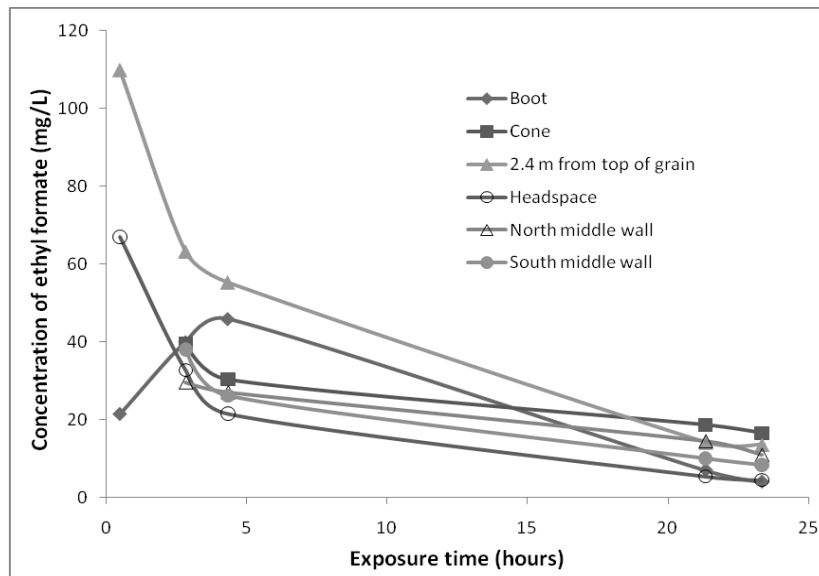


Fig. 3- Inter-granular concentrations of ethyl formate during the fumigation period of 24 hours.

Table 1. Concentration × time (Ct) products achieved at different locations within silo

Location of gas sampling ports	Concentration × time (Ct) products (g h m ⁻³)*
Boot	597.1
Cone	550.1
2.4 m from top of grain	909.1
Headspace	396.0
North middle wall	455.5
South middle wall	418.1

$$*. Ct = \sum (C_i + C_{i+1}) (t_i - t_{i-1}) / 2$$

Where: C is fumigant concentration (g m⁻³)

t is time of exposure (hours)

i is the order of measurement

Ct is concentration × time products (g h m⁻³)

DISCUSSION AND SUGGESTION

The experiment demonstrated liquid EF can be used as an emergency treatment in unsealed silos to control grain insects. The technique of pouring the liquid into the headspace was undertaken in consideration of the flammability of this product, allowing the EF time to vaporise and be partly absorbed as it passed through ~5 m of wheat before reaching the fan.

Emergence of *T. castaneum* after incubation is due to concentrations in the headspace below a Ct=450 g h m⁻³, shown as a reference level from the previous studies to eliminate all internal stages of the insects. (Ni et al., 2008).

It is suggested that the recirculation should be operated for a period longer than 2 h after full distribution of the vapour to ensure higher concentrations of EF are maintained through the unsealed grain bulk.

REFERENCE

Ni X, Ren YL, Forrester RI, Xue M and Mahon D (2008). Toxicity of Ethyl Formate to Adult *Sitophilus oryzae* (L.), *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (F.). Journal of Stored Product Research. 44(3), 241-246.