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FIELD EVALUATION OF ALUMINUM PHOSPHIDE FORMULATIONS AS A FUMIGANT FOR THE CONTROL OF STORAGE INFESTATIONS

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ABSTRACT

The NFA continuously searches for alternative pesticides that are cost effective. It had embarked on a research project to evaluate other commercially available fumigant formulations in the market such as Quickphos, which is suggested to be as effective as Phostoxin, the one currently used by the agency for PH_3 fumigations. Data obtained from an analysis of variance showed that as regards technical performance, Quickphos, when applied either in single or double dosage, exhibited the same effect as Phostoxin in the control of stored-product insects such as *Rhyzopertha dominica*, *Sitophilus* spp., and *Tribolium castaneum,* yielding 100% mortality. Regardless of the dosage used, gas concentration generated by Phostoxin was significantly higher than Quickphos. The gas concentration of a double dose of both fumigants was significantly higher than a single dose. The peak gas concentrations attained at different monitoring times did not differ significantly between the two fumigants tested. Furthermore the interaction of dosage and time in relation to gas concentration revealed a wide variety of responses with one variable having a more pronounced effect than the other. Economics-wise, Quickphos is cheaper than Phostoxin. The agency will be able to realize a substantial savings especially on fumigation, if the former is used in the administration of pest control.

INTRODUCTION

For the past years, the National Food Authority (NFA) has been using one type of phosphine-based fumigant in its pest control administration. It is very seldom that methyl bromide (MB) is used and only then in limited cases such as for ship fumigation. Furthermore, MB is scheduled to be phased-out by the year 2005 in the developed nations and 2015 in the developing nations, because of its effect as an ozone-depleting substance. Since fumigants available for use in the market will become fewer, there is an urgent need to identify and study other potential fumigants and formulations that are acceptable and cost effective substitutes for NFA use in the control of storage infestations..

Price (1985), noted that the development of resistance to an insecticide may be due to selection of a number of behavioral and physiological functions. Firstly, insects may acquire a behavioral trait, which causes them to avoid the toxin. In the case of a fumigant this may be manifested as a movement away from high concentrations of the gas. Other studies have shown that diversification of chemical usage in pest control is a sound strategy that should be adopted to prevent development of insect resistance to fumigants. Diversification will also help in the identification of other chemicals and formulations that should be both effective in terms of kill and cost.

Effectiveness of fumigants is only one of the factors to be considered in pesticide evaluation, and cost must also be taken into account. When several commercial brands of the same fumigant are available in the market it is a correct step for 'Management' to evaluate other formulations and compare them with the existing brand with regard to effectiveness as well as price. For this reason, the present study was undertaken to test other phosphine-based fumigants in order to address the above-mentioned concerns.

MATERIALS AND METHODS

Experimental Design

Fifteen experimental stacks of milled rice imported from China were set up in a warehouse to evaluate and compare two phosphine (PH_3) formulations. The experimental design used was a factorial analysis in complete block design (CBD). There were two main treatments namely, the PH_3 formulations Quickphos and Phostoxin and untreated stacks served as controls. Each main treatment was further sub-divided into two sub-treatments with each sub-treatment replicated thrice. Likewise, the untreated, control stacks, were replicated three times.

The 15 designated stacks of rice were subjected to fumigation using the following formulations at the following rates of application:

- Stacks 1-3: Fumigation with Quickphos at a rate of 2.31 tablets/tonne (NFA standard dose).
- Stacks 4-6: Fumigation with Quickphos at a rate of 4.62 tablets/tonne.
- Stacks 7-9: Fumigation with Phostoxin at a rate of 2.31 tablets/tonne (NFA standard dose).
- Stacks 10-12: Fumigation with Phostoxin at a rate of 4.62 tablets/tonne
- Stacks 13-15: Control (untreated).

Test insects

The test insects were major pests of stored rice (Anon. 1998) and were provided by the Bureau of Post-Harvest Research and Extension (BPRE). They consisted of 7 to 14 d old adults of the following species: the lesser grain borer *Rhyzopertha dominica*, either the rice weevil *Sitophilus oryzae*, or the maize weevil *Sitophilus zeamais* (not identified down to species), and the rust-red flour beetle *Tribolium castaneum*. The insects were provided with sterilized food media of milled rice for *R. dominica* and *Sitophilus* sp. and flour for *T. castaneum*.

These same food media were used during observation of the post-emergence of insect progeny.

Storage site and stack building procedure

The project site was at the NFA-NCR Puritan Warehouse No. 2, Punturin, Valenzuela, Metro Manila. The warehouse space was defined and then cleaned thoroughly prior to building of the stacks.

Re-stacking of the imported milled rice was carried out so that each stack contained 500 bags. A total of 12 stacks were built for treatments and 3 stacks for control. As the stacks were built, PVC sampling tubes, 5 cm in diameter and 10 cm long, each containing food media and 10 adults of *Sitophilus* sp., *T. castaneum*, and *R. dominica,* were placed in position at the second layer from the bottom, at the middle layer and at the second from top layer of each stack. At each layer 9 tubes were distributed by completely randomized design through draw-lots, amounting to a total of 27 tubes per stack. Also, simultaneous to building of the stacks, plastic tubing for monitoring gas concentrations was inserted into each stack at the following positions: the inner core at the second from bottom layer; at the middle; and at the second from top layer.

Fumigation procedure

After the stacks had been built, the standard operating procedure (SOP) of stack fumigation based on the manual prepared by the Technical Research Division (TRDD) of NFA entitled 'Manual On Procedures and Policies on Pest Control' was applied to all the 12 stacks at the above mentioned dosage application rates. The computed single dosages for Quickphos and Phostoxin were 58 tablets per stack and 116 tablets per stack for the double dosage. As this was a conventional type of fumigation under tarpaulins, the exposure period applied was seven days. Stacks were opened and aerated on the 8th day for a minimum of three hours.

Data gathering

Insect Mortality: The 27 sampling tubes from each stack were retrieved after fumigation and the dead and live insects of each species were counted. These figures were then converted to % mortality. In principle, these mortalities were then corrected by taking into account mortalities not due to fumigation. This is done by calculating mortalities in the control stacks and applying Abbott's formula (Abbott, 1925).

Post-emergence of insect progeny on treated samples: The food media that were present inside the sampling tubes were retrieved and transferred to plastic petri dishes and observed daily for 14 d for possible post-emergence of insect progeny.

Phosphine gas concentration monitoring: PH_3 concentrations were measured using a Dräger pump to withdraw gas samples through the plastic tubing previously installed in the stacks. PH_3 indicator tubes attached to the Dräger pump were used to measure gas concentrations in ppm inside the stacks. The tubes give a color reaction (usually violet) that enables the PH_3 concentration to be read directly from a scale marked along the tube. Gas concentrations were monitored 6, 12, and 24 h after fumigant application and on days 2, 4, and 7 (Anon. 1986).

RESULTS AND DISCUSSION

Insect mortality

The fumigations were so effective that there was no need to apply Abbott's Formula, since all sampling tubes revealed 100% mortality of all test insects.

Fumigant efficacy

The effectiveness of Quickphos and Phostoxin as test fumigants was evaluated by comparing the levels of insect mortality obtained. Table 1 shows that the fumigant formulations under investigation effectively killed all the test insects. Under these circumstances there was no need to carry out statistical analyses, particularly since both the recommended dose, and double the recommended dose of both formulations achieved the same effect.

TABLE 1
Percent mortality of different insect species, as affected by treatments and dosages, after fumigation of 350 tonnes stacks of rice with Quickphos and Phostoxin

Treatments	Dosage (tablet/tonne)	Insect Species	Replicate 1	Replicate 2	Replicate 3	Mean
Quickphos	Single (2.31)	*R. dominica*	100	100	100	100
		Sitophilus spp.	100	100	100	100
		T. castaneum	100	100	100	100
	Double (4.62)	*R. dominica*	100	100	100	100
		Sitophilus spp.	100	100	100	100
		T. castaneum	100	100	100	100
Phostoxin	Single (2.31)	*R. dominica*	100	100	100	100
		Sitophilus spp.	100	100	100	100
		T. castaneum	100	100	100	100
	Double (4.62)	*R. dominica*	100	100	100	100
		Sitophilus spp.	100	100	100	100
		T. castaneum	100	100	100	100
Control		*R. dominica*	25.6	24.4	25.5	25.2
		Sitophilus spp.	33.3	42.2	75.6	50.9
		T. castaneum	3.3	2.2	0.0	1.9

Phosphine concentration monitoring

Gas concentration generation was another characteristic of the two fumigants that was monitored in this project. Statistical analysis was applied to the various factors (fumigant formulation, dosage, and time) as they affect PH_3 concentrations.

Here, analysis of variance showed that the replications of treatments yielded no significant differences, meaning that the data gathered from the replicated stacks were very similar to each other. However, all the other factors were found to be significant at the 1% level of significance. Duncan's multiple range test (DMRT) was employed and revealed that regardless of dosage used, the gas concentration obtained with Phostoxin was significantly higher than that obtained with Quickphos. These finding can be seen in Table 2. Clearly, the gas concentrations using double doses of fumigant were significantly higher than the single dose and this applies to both formulations. Figure 1 shows the PH_3 concentrations generated by Quickphos and Phostoxin. For both formulations, the PH_3 concentrations reached their peak after 48 hours giving a mean concentration of 1,513 ppm. Figure 2 showing the mean concentrations over time, clearly illustrates the rise and decay of the fumigant concentration curves.

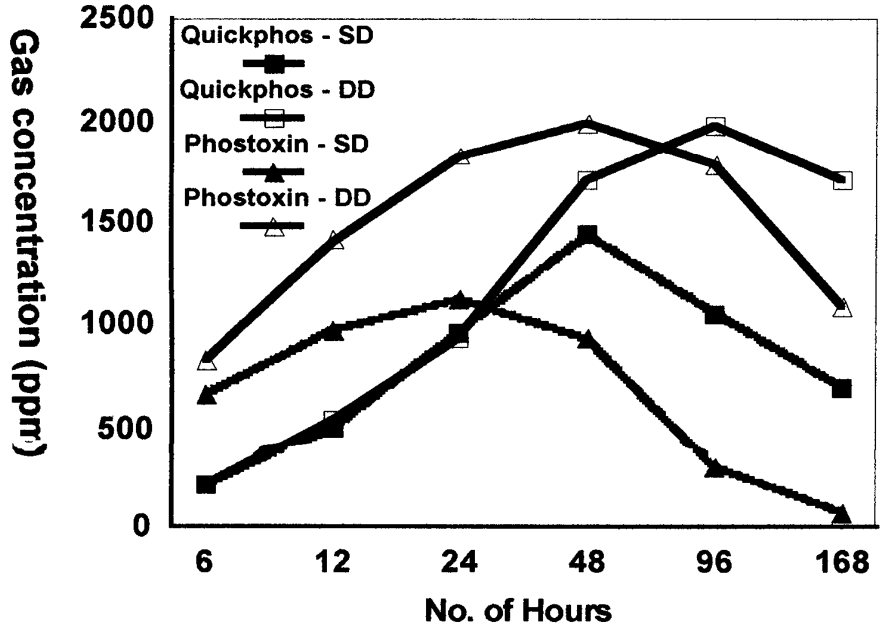

Fig. 1. Phosphine (PH_3) concentrations (in ppm) during standard stack fumigations of rice using Quickphos and Phostoxin formulations. (SD - single dose, DD - double dose).

Treatments and dosage levels

The NFA has set a recommended dosage for fumigation administration (Donceras *et al.,* 1992). The rate usually depends on the condition of the stocks (degree of infestation) and also on the kind of pest present in the commodity. Usually a maximum dosage of 2.31 tab/tonne is being recommended on stocks that are highly infested. This, however, increases to a recommended dosage of 4.62 tab/tonne in cases where severe infestation is noted and where the presence of major pests particularly *Trogoderma granarium* (Everts) is also observed.

When considering the relationship between the two formulations and dosage, an analysis using Duncan's multiple range test revealed that the single dose of the two formulations produced concentrations that were not significantly different from each another. However, when the dosage was doubled, a significant difference between the two formulations was recorded. Although, several studies have pointed out that there are different factors that influence gas concentration generation in a given enclosure, namely: temperature and relative humidity prevailing within the enclosure; the gastightness level of the fumigated structure; the permeability characteristics of the fumigation sheeting; and sorption of the fumigant by the commodity, in this case all these factors were similar for each formulation and therefore the difference must be inherent in the formulations themselves.

TABLE 2
Phosphine gas concentrations monitored during fumigations of 350 tonne stacks of rice with Phostoxin and Quickphos

Fumigant	Dosage (tablets/ tonne)	Monitoring time (h)	Mean
Phostoxin	Single Dose (2.31)	6	661
		12	967
		24	1117
		48	925
		96	294
		168	69
	Double Dose (4.62)	6	828
		12	1406
		24	1825
		48	1989
		96	1775
		168	1083
Quickphos	Single Dose (2.31)	6	206
		12	492
		24	961
		48	1431
		96	1050
		168	491
	Double Dose (4.62)	6	200
		12	536
		24	933
		48	1709
		96	1972
		168	1708

Post-emergence of insect progeny

Immediately after the 7-day fumigation period and aeration of stacks, the different media from the test tubes were retrieved and placed in the plastic petri dishes for 14-day monitoring of larval emergence. The results obtained showed no-emergence of progeny of any of the test insects both for the Quickphos and Phostoxin formulations.

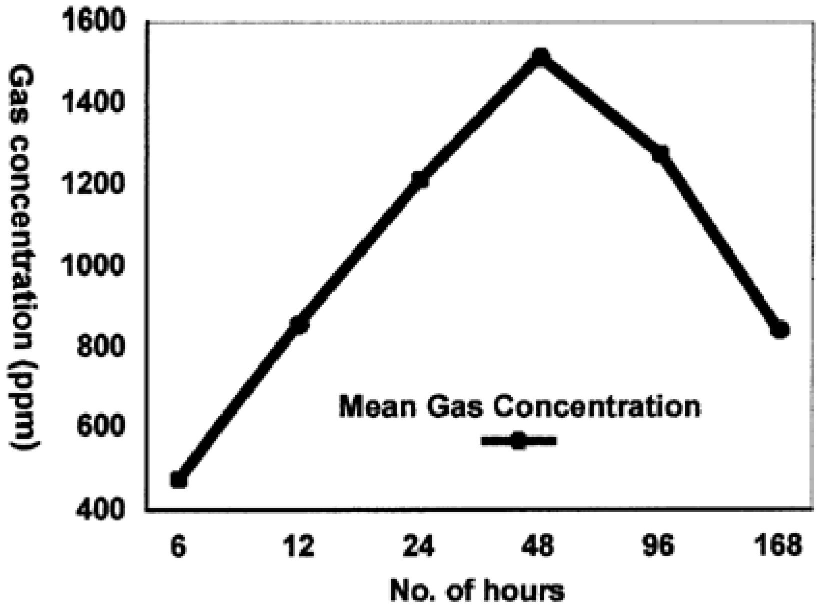

Fig. 2. Mean phosphine (PH_3) concentrations (in ppm) of both fumigant formulations (Quickphos and Phostoxin) during standard stack fumigations of rice.

Economic Analysis

Table 3 shows a comparative cost analysis of the two aluminum phosphide based fumigant formulations, Quickphos and Phostoxin. It shows that when investment, fixed, labor, and supplies and material costs are equal, Quickphos is cheaper by (Philippine Peso) PhP 1.32 than Phostoxin for the fumigation of a 350 tonne stack of rice. More specifically, the total operating cost for Phostoxin amounted to PhP 8,259.27 compared to PhP 7,798.43 for Quickphos'. On the basis of cost of application per metric ton, the former costs PhP 23.60/tonne while the latter costs PhP 22.28/tonne. (1 US$ ≈ 50 PhP).

CONCLUSIONS

From aspects of technical performance, the newly tested fumigant formulation Quickphos was comparable to Phostoxin, producing 100% mortality in adults of all three stored-product insects tested (*R. dominica*, *Sitophilus* sp. and *T. castaneum*). This was true regardless of the dosage used (the recommended dose or double the dose). The peak gas concentrations were attained at 48 hours. The results obtained by monitoring gas concentrations showed that single dosages of Quickphos and Phostoxin were insignificantly different from each other, whereas gas concentrations from double dosages of both formulations were found to be significantly different from each other.

Cost wise, Quickphos was cheaper at PhP 22.28/tonne compared to Phostoxin at PhP 23.60/tonne. A savings of PhP 1.32/tonne was realized in favor of Quickphos.

RECOMMENDATION

The newly tested fumigant formulation Quickphos, is highly recommended to be incorporated into the agency's Pest management program as it answered both the technical and economic aspect of the evaluation.

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