FUMIGATION EXPERIMENTS WITH PHOSPHINE IN TRADITIONAL MUD SILOS IN EGYPT TO CONTROL STORED PRODUCT INSECTS.

by

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ABSTRACT

Fumigation experiments carried out in Egyptian traditional mud silos using PHOSTOXIN^{R}- Tablets showed that phosphine was effective against the following insect species : Sitophilus oryzae ; Sitotroga cerealella ; Rhizopertha dominica ; Alphitobius diaperinus ; Tribolium spp. and Trogoderma granarium.

Data showed that mortality percentages ranged between 93- 100 % and 65 - 100 % in case of adults and immature stages respectively. The toxicity correlated with the dosages used as well as period of fumigation . The concentration of the gas sharply decreased as time lapsed from the onset of fumigation.

Two fumigation techniques were used in these trials. In the first technique the mud silo was completely covered with DETIA cover sheet and in the second one only the top of the mud bin was covered.

The first technique gave better results and proved to be feasible , efficient and safe and thus could be recommended for the fumigation of grain stored in the mud bins in the villages.

INTRODUCTION

Insects are a major cause of postharvest grain losses. By boring within the kernels and feeding on the surfaces , they remove food , selectively consume nutritive components , encourage higher moisture in the grain , and promote the development of microorganisms.

Under ideal conditions the use of gastight silos should facilitate virtually hermetic storage of grain , thus inhibiting the development of insect infestation and consequent damage.

Phosphine (PH_3) has come into prominence in recent years as an effective fumigant to control stored product insects. It is highly toxic to insects (Lindgren et al , 1958 ; Lindgren and Vincent , 1966) and was ranked as one of the most toxic fumigants to postharvest insects (Bond and Monro , 1961). Phosphine did not impair the germination of seeds (Strong and Lindgren , 1960 ; El-Lakwah and Metwally , 1989).

It has been mentioned that the CT-product of PH_3 cannot be used as a sole measure of the lethal effect of phosphine against insects and that the time is often a more important factor than the concentration. How , 1973 reported that

insects pass through resistant and susceptible stages and if fumigation is carried on for a sufficient length of time the resistant stages will develop into a more susceptible stage providing that temperatures are high enough. This is why temperature is so important in the effective use of phosphine and it also emphasises the need for a sufficiently long exposure period.
The traditional mud silos are spreaded on farmers level allover Egypt. These silos , constructed from clay and chopped wheat-straw, have various sizes and forms such as (conical , spherical and pear-shaped). The silos are often located on the roof of the farmers houses in the villages , sometimes inside the rooms , or infront the houses. The capacity of the mud bin ranges from 80 - 1500 kg and it has two openings , one on the top for inlet of the grain and the other one on the side at the base of the silo as outlet. The silos are often covered with a lid made of the same materials used in their construction , or made of wood or other materials. In the different Governorates of Egypt , the following agric. products are stored in such silos : wheat , maize , rice , beans , barley , peanuts , sorghum (millet) , onions and dates. The storage period of these commodities varies from 3 to 12 months.
Wohlgemuth and Reichmuth , 1987 studied the effectiveness of phosphine against Sitophilus zeamais (Motschulsky) and Sitotroga cerealella (Olivier) by carrying out fumigation experiments in traditional mud silos (Banco silos) in West Africa.
In this work , fumigation experiments using phosphine were carried out in the traditional mud silos in Egypt to study the effectiveness of this gas , under this condition , against some stored product insects.

MATERIAL AND METHODS

The experiments were carried out in mud silos located on the roof of one of the farmers houses at Moshtohor-village , Kalyubia Governorate. The silos were filled with wheat and maize on the cob.
Phosphine produced from PHOSTOXIN^{R}-Tablets (a product of DEGESCH Co. Frankfurt am Main - West Germany) , was used in the trials.
The tablet contains approximately 56 % aluminium phosphide which reacts with water producing PH_3 ; one tablet weighs about 3 g and yields 1 g of phosphine.
Phosphine concentrations inside the silo , were determined during the fumigation with DRAEGER gas detector tubes (50 / a and 0.1 / a). For monitoring of phosphine outside the bin , DRAEGER tubes for measuring low concentrations, were used.

Prior the fumigation the temperature of the grain and the relative humidity inside the silo were measured and recorded.

DETIA cover sheets (DETIA Folie) were used to cover the whole mud silo during some fumigation trials and in other experiments only the top of the bin was covered. The base opening was closed with mud and straw before filling the bin with the grain (see Figures 1 and 2) .

In the bioassay tests , the adult stages of the following insect species were examined :

Rice weevil, Sitophilus oryzae (L.) ; Angoumois grain moth, Sitotroga cerealella (Olivier) ; The lesser grain borer, Rhizopertha dominica (F.) ; The lesser meal worm, Alphitobius diaperinus (Panzer) ; and the flour beetles, Tribolium spp.

The immature stages of S. oryzae (L.) and S. cerealella (Oliv.) as well as the larval stages of the Khapra beetle, Trogoderma granarium (Everts) were also tested.

These insects were obtained from cultures reared in the laboratory at 26 ± 1° C and 65 ± 5 % RH. The rearing medium was wheat for the weevils , the moths , the Khapra beetle and wheat flour for the Flour beetles.

Wire gauze cages (13 cm length and 1.4 cm diameter) were filled with about 3 g wheat grain for the adult insect stages and the larval stages of the Khapra beetle. Batches of 50 insects were added to each cage . In case of the immature stages , about 5 g infested wheat grain were put in the cage . Before the fumigation of the silo , the wire gauze cages for the adults and immature stages of the insects , were inserted into the grain at various depths using a steel probe.

The mortality of the adult stages was recorded after 3 days and for the larvae of Khapra beetle after 7 days from the end of the fumigation. For the immature stages of S. oryzae and S. cerealella the mortality was obtained after 5 - 6 weeks. This period was sufficient for emergence of all weevils and moths in the treatments as well as the control. The percentage of mortality was calculated by using the following equation (Mostafa et al , 1972) :

$$\% \text{ mortality} = 100 - \left(\frac{X}{Y} \cdot 100 \right)$$

where X = No. of adults emerged in the treatment.

Y = No. of adults emerged in the control .

Figure (1): Mud silos of various sizes.

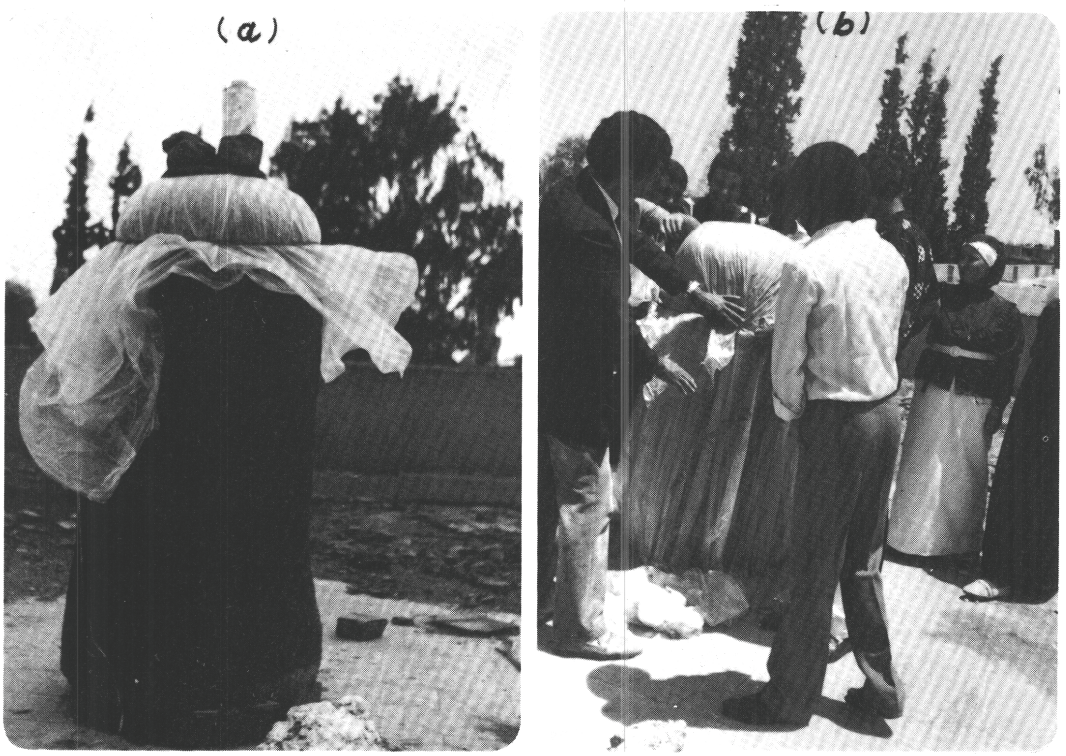

Figure (2): a. Mud silo during fumigation, the top only was covered with Detia cover sheet.

b. Covering the mud silo completly with Detia cover sheet.

The dimensions of the silos were :
Silo A : the total volume was 0.4 m^3 (height = 140 cm , diameter = 60 cm , opening inlet = 18 cm , wall thickness = 7 cm, base opening = closed).
Silo B : the total volume was 0.3 m^3 (height = 134 cm , diameter = 36 cm , opening inlet = 20 cm , wall thickness = 7 cm , base opening = closed) .

RESULTS AND DISCUSSION

The results of the experiments , carried out during the period from February 22 to July 7 , 1986 are shown in tables 1 and 2 . In these trials two mud silos , which were loaded with 80 kg wheat grain and 80 kg maize on the cob , were fumigated using various dosages of phosphine (1 - 8 tablets / silo). Phosphine tablets were put in a petri dish and placed on the surface of the grain . Before fumigation the top of each silo was covered with DETIA cover sheet and fixed with a rubber band . The fumigation time ranged between 48 to 72 hours , and the gas concentrations were measured at two depths (near the top and next to the base of the bins) .
Data indicated that the application of 1 tablet as well as 2 tablets for each silo and a fumigation period of 72 hours were not sufficient to achieve a 100 % mortality for the adult and immature stages in all insect species examined in the bioassay test ; but the use of 4 to 8 tablets / silo / 72 hours resulted in a 100 % mortality for the adult and immature stages of all insect species.

Measurements of phosphine concentration revealed that the gas was nearly distributed equally within the grain . The increase of the concentration was proportional to the dosage used . The phosphine concentration declined rapidly towards the end of the fumigation period , this was more noticeable during the days with high outdoor temperature.
The phosphine concentration in the surrounding atmosphere of the bins was found in range 0.1 - 3. 0 vpm , when the gas concentration between the grain were from 300 - 500 vpm , and no traces of the gas were detected in the room under the silos .

Additional experiments were conducted from October till December 1986 , using the same mud bins as mentioned in the previous trials and the same fumigation technique. The quantity of wheat stored in the mud silo was increased to 220 kg , and in some experiments (No. 8 and 9) the dosage of phosphine was halved by putting one portion in a petri dish on the surface of the grain and

Table 1: The concentrations of phosphine detected in the grain and mortality recorded for the experiments 1-11 conducted during February to July 1986.

Exp. No.	Date of fumig.	Commod. in the silo	Air temp. °C min.	Air temp. °C max.	Mean temp. of grain °C	RH %	Dosage No. of tablets	Fumig. period h	meas. place	Concentration of pH_3 (vpm) after 24 h	48 h	72 h	No. of survivals	Mortality %	Remarks
1	24.2.	Maize	9	23	17	50	8	72	a	420	370	220	0	100	
									b	430	380	180			
		Wheat	9	23	18	55	8	72	a	450	240	60	0	100	
									b	470	280	80			
2	10.3.	Maize	11	22	18	50	8	72	a	200	70	20	0	100	
									b	320	100	20			
		Wheat	11	22	18	50	8	72	a	300	210	200	0	100	
									b	300	200	190			
3	15.3.	Maize	13	24	19	50	4	72	a	250	100	20	0	100	
									b	260	80	30			
		Wheat	13	24	19	50	4	72	a	300	100	60	0	100	
									b	320	120	60			
4	22.3.	Maize	14	26	20	45	2	72	a	80	10	2	2	93	larvae of T. granarium
									b	60	10	1			
		Wheat	14	26	20	45	2	72	a	80	40	10	0	100	
									b	100	40	8			
5	29.3.	Maize	-	-	-	-	-	-	a	-	-	-	-	-	
									b						
		Wheat	10	21	17	45	2	72	a	150	50	2	0	100	
									b	120	60	1			
6	7.4.	Maize	-	-	-	-	-	-	a	-	-	-	-	-	
									b						
		Wheat	12	22	17	45	1	72	a	50	10	0.1	6+2	75-93	6 of T. gran. larvae 2 S. oryzae.
									b	60	8	0.1			
7	14.4.	Maize	11	20	16	50	2	72	a	80	2	0.1	2+21	65-93	larvae of T. granarium S. oryzae
									b	100	3	0.1			
		Wheat	-	-	-	-	-	-	a						
									b	-	-	-	-	-	
8	2.7.	Maize	21	36	32	45	2	48	a	50	20	-	0	100	
									b	60	15	-			
		Wheat	-	-	-	-	-	-	a						
									b	-	-	-	-	-	
9	14.7.	Maize	20	36	34	52	4	48	a	300	10	-	0	100	
									b	300	10	-			
		Wheat	20	36	33	52	4	48	a	70	30	-	0	100	
									b	80	20	-			
10	19.7.	Maize	21	36	33	55	8	48	a	500	25	-	0	100	
									b	520	30	-			
		Wheat	21	36	32	55	8	48	a	200	50	-	0	100	
									b	180	50	-			
11	22.7.	Maize	23	36	33	55	2	48	a	50	10	-	0	100	
									b	55	20	-			
		Wheat	23	36	33	55	2	48	a	40	5	-	0	100	
									b	45	2	-			

a = near to the top of the silo.; b = next to the base of the silo

Table 2: Mortality of insect species examined in the experiments 1-11.

Exp. NO.		No. of survivals for						% Mortality for					
		S. oryzae	adults of T. castaneum	R. dominica	A. diaperinus	larvae of T. granarium	immature stages of S. oryzae	S. oryzae	adults of T. castan.	R. dominc.	A. diaper.	larvae of T.granarium	immature stages of S. oryzae
1	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	0	0	0	0	0	0	100	100	100	100	100	100
2	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	0	0	0	0	0	0	100	100	100	100	100	100
3	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	0	0	0	0	0	0	100	100	100	100	100	100
4	A	0	0	0	0	2	1	100	100	100	100	93	98
	B	0	0	0	0	0	0	100	100	100	100	100	100
5	A	-	-	-	-	-	-	-	-	-	-	-	-
	B	0	0	0	0	0	0	100	100	100	100	100	100
6	A	-	-	-	-	-	-	-	-	-	-	-	-
	B	2	2	0	0	6	15	93	93	100	100	80	75
7	A	0	0	0	0	2	21	100	100	100	100	93	65
	B	-	-	-	-	-	-	-	-	-	-	-	-
8	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	-	-	-	-	-	-	-	-	-	-	-	-
9	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	0	0	0	0	0	0	100	100	100	100	100	100
10	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	0	0	0	0	0	0	100	100	100	100	100	100
11	A	0	0	0	0	0	0	100	100	100	100	100	100
	B	0	0	0	0	0	0	100	100	100	100	100	100

A=Silo loaded with maize on cob , B=silo loaded with wheat grain

the other one was inserted in the grain . The results obtained are shown in Table 3 . The figures revealed that the gas concentration detected near the top of the bin containing wheat was higher than the one near the base of the silo , when the whole amount of phosphine tablets was placed on the surface of the wheat . On the other hand the phosphine concentration was uniformly distributed within the wheat when half the dosage was inserted in the wheat and the other half placed on the surface of the wheat.
Regarding maize on the cob the concentration of phosphine was , however , equally distributed inside the silo when the total amount of phosphine was placed on the surface of the maize .

The bioassay tests showed that a 100 % mortality was observed for the adult and immature stages of the insect species by using various dosages (2 , 4 , and 6 tablets per each silo) and after a fumigation period of 72 hours for the maize silo . The same result was obtained with wheat silo using 4 and 6 tablets only ; but the application of the lowest dose (2 tablets / silo /72 hours) under the same experimental conditions appeared to be unsufficient to obtain a 100 % kill of all insect species , because some larvae of Trogoderma granarium and immature stages of S. oryzae survived the fumigation.

In 1987 (April - May) , 3 further fumigation experiments were conducted by using a modified fumigation technique . The mud bin was completely covered with DETIA cover sheet , and fixed at the bottom with a rubber band .
The silo was filled with 220 kg wheat grain up to the top , the dosage of phosphine was between 1 and 2 tablets / silo , and the fumigation period was 48 and 72 hours . Temperatures ranged between 13 - 29 ^{o}C , 12 - 27 ^{o}C , and 18 - 34°C in case of the three experiments , respectively . The corrosponding relative humidity ranged between 45 - 50 % , 45 - 50 % , and 45 - 55 % . The temperature of the wheat grain was 20°C , 18°C , and 20°C for the first , second , and third experiment , respectively . The results of these trials were presented in Tables 4 and 5 .
Data showed , that the concentration of the gas was , however , equally distributed inside the wheat grain , although the total quantity of PHOSTOXIN - Tablets was placed on the surface of the grain . The mean value of phosphine concentrations obtained by this fumigation technique was significantly higher than that detected in the previous experiments in which only the top of the silo was covered and provided with the same phosphine dosage . The mortality of the test insects (see Table 5) revealed a 100 % mortality for adult and

Table 3: Concentrations of pH_3 and mortality of test insects for the experiments conducted during October to December 1986.

Exp. No.	Date of fumig.	Commodity inside silo	Air - temp. °C min.	Air - temp. °C max.	RH %	Ø Temp. of grain °C	Dosage (Tablets)	Concentrations of pH_3 (Vpm) after measur. place	24 h.	48 h.	72 h.	Fumig. period h.	No. of survivals	Mortality %
1	14.10.68	Wheat	17	28	60	18	4*	a	1000	40	5	72	0	100
								b	500	20	5			
2	20.10.86	Wheat	21	30	55	19	4*	a	1500	600	1	72	0	100
								b	700	50	1			
3	27.10.	Wheat	19	28	55	20	6*	a	1200	300	1.5	72	0	100
								b	800	200	1.0			
4	1.11.	Wheat	13	24	55	16	2*	a	40	8	6	72	3 W.	98
								b	20	6	1.5		2 L.	93
5	18.11.	Maize	12	27	65	17	4*	a	210	50	10	72	0	100
								b	210	50	10			
		Wheat	12	27	65	17	2*	a	100	40	1	72	0	100
								b	50	20	1			
6	25.11	Maize	14	24	70	18	2*	a	80	20	1	72	0	100
								b	70	10	1			
		Wheat	14	24	70	18	2*	a	20	12	0.5	72	5 W.	96
								b	10	3	0.5		4 L.	87
7	29.11.	Maize	12	18	65	16	6*	a	200	110	70	72	0	100
								b	200	100	60			
		Wheat	12	18	65	16	6*	a	400	40	8	72	0	100
								b	40	20	8			
8	2.12.	Wheat	10	18	65	15	(3+3)**	a	130	70	20	72	0	100
								b	130	60	20			
9	6.12.	Wheat	7	20	65	14	(3+3)**	a	110	50	30	72	0	100
								b	90	60	30			

a = Concentrations near the top of the silo
b = Concentrations next to the base of the silo
* = Total dosage was placed on the surface of grain
** = Dosage was halved; one portion put on the surface and the other one inserted in the grain.

W = Weevils from immature stages of S. oryzae.
L = Larvae of T. granarium

Table 4 :Concentrations of PH_3 detected for the experiments conducted during 1987

Exp. No.	Fumig. date	Dosage (Tablet)	Fumig. period h	Measur. place	Concentrations of PH_3 (vpm) after 24h	48h	72h
1	21.4.	2	72	a	1350	1000	250
				b	1300	900	200
2	28.4.	1	72	a	700	50	20
				b	650	40	10
3	5.5.	1	48	a	700	50	-
				b	700	50	-

a= near to the top of the silo
b= next to the base of the silo

Table 5 : Mortality of test insect species for the experiments of 1987

Insect species	Exp. No. 1		Exp. No. 2		Exp. No. 3	
	No. of survivals	mortality %	No. of survivals	mortality %	No. of survivals	mortality %
Adult stages of :						
S. oryzae	0	100	0	100	0	100
Tribolium spp.	0	100	0	100	0	100
S. cerealella	0	100	0	100	0	100
immature stages of :						
S. oryzae	0	100	0	100	0	100
S. cerealella	0	100	0	100	0	100

immature stages of all insect species examined , and this means that using such a cover sheet by wrapping the mud bin completely had made the porous mud silo relatively gas tight , and therefore could be considered as suitable and easy method to fumigate the commodities stored in such silos .

The application of such technique would be feasible on farmers' level in Egypt , if all precautionary fumigation measures during storage and use of phosphine tablets would be carefully carried out , to avoid the risks of the very toxic phosphine gas . The risks of the gas could be banned , if the fumigation of the mud silos will be conducted by or under the supervision of a trained staff.

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LES EXPERIENCES DE FUMIGATION A LA PHOSPHINE A L'INTERIEUR DES SILOS DE BOUE SECHEE TRADITIONNELS EGYPTIENS POUR LA DESTRUCTION DES INSECTES DES DENREES STOCKEES

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RESUME

Les expériences de fumigation entreprises dans les silos de boue séchée traditionnels en Egypte par emploi de comprimés de PHOSTOXIN ont montré que la phosphine était efficace dans la lutte contre les insectes suivants : *Sitophilus oryzae, Sitotroga cerealella, Rhizopertha dominica, Alphitobius diaperinus, Tribolium spp* et *Trogoderma granarium*. Deux techniques de fumigation ont été étudiées dans ces essais. Dans la première, le silo de boue a été complètement recouvert avec une bâche DETIA et dans la seconde, seul le sommet du silo de boue a été couvert. La première technique s'est avérée la plus efficace. Elle s'est également avérée réalisable et sûre et, peut être donc être recommandée pour la fumigation du grain stocké en silos de boue séchée dans les villages. On peut bannir tout risque de toxicité dû à la phosphine si toutes les précautions d'usage lors de la manipulation des comprimés sont prises.