Study on effective fumigation in Indian warehouses

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Abstract

An effective fumigation requires that the phosphine gas at lethal concentrations is held in the infested stocks long enough to kill all stages of the target pests. Loss of measurable phosphine gas results due to absorption by grain, permeation through fumigation sheets and leakages through holes and gaps etc. Permeability of gas proof sheets is influenced by both the material and thickness of gas sheeting. The fumigation sheets/covers upon repeated use, due to handling stress are likely to lose their gas retention property to a great extent. Good sealing is equally important when fumigations are done with phosphine in view of longer exposure period. A study was taken up in six states in India *viz*., Haryana (Karnal), Uttar Pradesh (Shajahanpur), Madhya Pradesh (Morena), Gujarat (Baroda), Andhra Pradesh (Gudivada, Machilipatnam and Rajamundhry) and TamilNadu (Trichy and Thanjavur) to determine the effectiveness of Multi Layered Cross Laminated (MLCL) fumigation covers of 200 GSM thickness with proper sealing materials in retaining the applied phosphine gas and also to kill the insects effectively. The phosphine concentration was measured at 6 hrs, 24 hrs, 2 days, 3 days, 5 days, 7 days and 10 days before termination of fumigation to see the insect mortality. The results revealed that the phosphine gas retention was generally good and it was sufficient to kill all the stages of insects. Hundred per cent mortality of insects was observed with 2 or 3 tablets and /short or longer exposure periods. However few populations of *Cryptolestes* were survived in treatment with 3 tablets for 7 days.

Keywords: exposure, fumigation, mortality, phosphine, sealing

1. Introduction

A high record of 263.20 million tonnes of food grain was recorded in India during 2012-2013, with 3.91 million tonnes more than the 259.29 million tonnes produced in 2011-12, making it the highest ever food grain production the country has seen. The estimate showed rice output at 106.19 million tonnes, as against 105.24 million tonnes produced in 2012-13, and wheat at 95.60 million tonnes compared to 93.51 million tonnes last year (Anonymous, 2014). There was a tremendous flow of grains across the country in this decade. To manage million tonnes of food grains, India entirely dependent on Phosphine as the fumigant for disinfesting grain stacks. Phosphine is cheaper, and have a deep penetrating ability and easy to apply on grain, does not affect the quality even after repeated applications and the phosphine dust residue problem was insignificant. Although the application of phosphine is simple when compared with methyl bromide, insect mortality results are, reported to be unsatisfactory under practical applications.

Storage is an inevitable phase in the post harvest chain of food grains. Large harvest, poor market demand, food security during and off-season processing are some of the factors that force farmers and traders to store grains and oilseed crops (Alagusundaram, 2009).

In India, about 70% of farm produce is stored by farmers for their own consumption. The official storage capacity grew from 1.3 million tonnes in 2007-08 to 71.8 million tonnes in

2012-13 representing 54 per cent increase. Bag storage is largely practiced in India, mainly because of the ease in handling and transport. A recent study by the Food and Agriculture Organization (Gustavsson, et al., 2011) reported that one-third of all food produced for human consumption is lost or wasted globally, amounting to as much as 1.2 billion metric tonnes annually.Post-harvest losses in India amount to 12 to 16 million metric tons of food grains each year, an amount that the World Bank estimates could feed one-third of India's poor. The monetary value of these losses amounts to more than Rs. 50,000 crores per year (Singh, 2010).

Aluminium Phosphide tablets are widely used in India for the control of stored pests. Phosphine has a specific gravity of 1.21, similar in density to air, which allows it to spread and penetrate well through commodities and structures. The effectiveness of phosphine fumigation is determined by the concentration of the gas, the temperature, and the length of time the gas can be held on the target pest. Gas concentration is a function of gas-tightness of the fumigation cover and floor sealing and the total amount of fumigant added to the commodity.

2. Materials and Methods

An experiment was conducted in six states *viz*., Haryana (Karnal), Uttar Pradesh (Shajahanpur), Madhya Pradesh (Morena), Gujarat (Baroda), Andhra Pradesh (Gudivada, Machilipatnam and Rajamundhry) and TamilNadu (Trichy and Thanjavur) to study the PH_3 concentration and insect mortality studies. The treatment details are given in Table 1.

2.1. Efficacy of phosphine fumigation in different warehouses

The experiment was conducted in covered warehouses. A stack size of 30'X20' was maintained for the study. The new brand cover Multi Layered Cross Laminated 200 GSM was used as a fumigation cover. To know the phosphine concentration transparent hose of 0.5 cm (dia) was suspended from top, middle and bottom layers up to the floor level and the terminal ends of the tubes were closed tightly. Aluminium phosphide tablets (3 tablets/tonne) were placed below the wooden dunnages and finally floor sealing materials like sand snakes and surgical tape were used to prevent the leakage of gas. Raw rice was used in all the stacks used for fumigation. The PH_3 concentration was measured using UNIPHOS PH_3 monitor (Figure 2).

2.2. Mortality of insects in the PH_3 fumigated stacks

Due to sublethal dosages, due to leakage, less exposure period there are chances for buildup of resistance population .To study the insect mortality, different insect species *viz.*, *Sitophilus* spp., *Tribolium* spp., *Rhizopertha* spp. and *Cryptolestes* spp. were used as a test insect for the study. Two and Three tablets were used for the study with seven and ten day's exposure. Two tablet treatments were not used for *Cryptolestes* spp. study. Known number of insects were released in plastic vials with sufficient food materials (flour, broken rice and little yeast). The vials were covered with a muslin cloth and secured with a rubber band. The vials were taken out after fumigation study and observed for mortality. The vials were kept for three months to note the further emergence of insects. Post emergence of population was studied after a month period.

Table 1 Treatment Details of the PH_3 retention study.

Treatments	Particulars (3g tablet)	Exposure period (days)	Method of sealing
T1	2 tablets/MT	7	Sand Snakes
T2	2 tablets /MT	10	Sand Snakes
T3	3 tablets /MT	7	Sand Snakes
T4	3 tablets /MT	10	Sand Snakes
T5	3 tablets /MT	10	Tape
T6	Control (No fumigation)	10	Sand Snakes

3. Results and Discussion

3.1. Efficacy of phosphine gas retention in warehouses

The study was carried out in Central Warehousing Corporation.PH_3 gas concentration was measured in top, middle and bottom layers. In India there is an increased awareness about monitoring gas concentrations in grain stack due to resistance of insects.PH_3 meters (1-2000 ppm) measuring range was used for the study in warehouses. The study carried out in Thanjavur (Tamil Nadu) results revealed that PH_3 gas concentration was uniformly distributed in all the 3 layers. PH_3 concentration was more in T_1 and T_2 at 3rd day with 1772 ppm in all layers. In T3 maximum PH_3 gas retention was 1417.33 ppm at 2nd day in the top layer. In T5 gas retention was more on 2nd to 5th day and maximum of 1772.0 ppm was recorded Figure 1. To prevent the development of resistance, it is essential to avoid applications with sub-lethal doses (Fields &White, 2002).

In Gudivada**,** PH_3 gas concentration was a maximum of 1645 ppm in T4 and 1363.22 ppm in T2 on 2nd day. The study in Morena revealed that PH_3 retention was less in T1, T2 &T3.In T4 & T5 PH_3 retention was slightly increased with a maximum of 1021.22 ppm and 1055.44 ppm on 7th day. In general the phosphine retention was good in all the treatments. Results in Baroda revealed that PH_3 gas retention was more on 2nd day and 3rd day in T3 and T4 with a maximum of 1731.33 and 1781.22 ppm. Whereas, maximum retention was noticed in T5 with 1829.22 ppm on 2nd day. Shahjahanpur results revealed that PH_3 gas retention was more in T4 (1832.33 ppm) on 7th day. Karnal results revealed that PH_3 gas retention was more on 5th day with a gas concentration of 1458.33 ppm in T4 and 1684.66 ppm in T5 on 10th day (Table 2). In the present study, retention of phosphine was more in Multi Layered Cross Laminated sheets and these findings was accordance with the earlier findings (Rajendran et al., 2003).

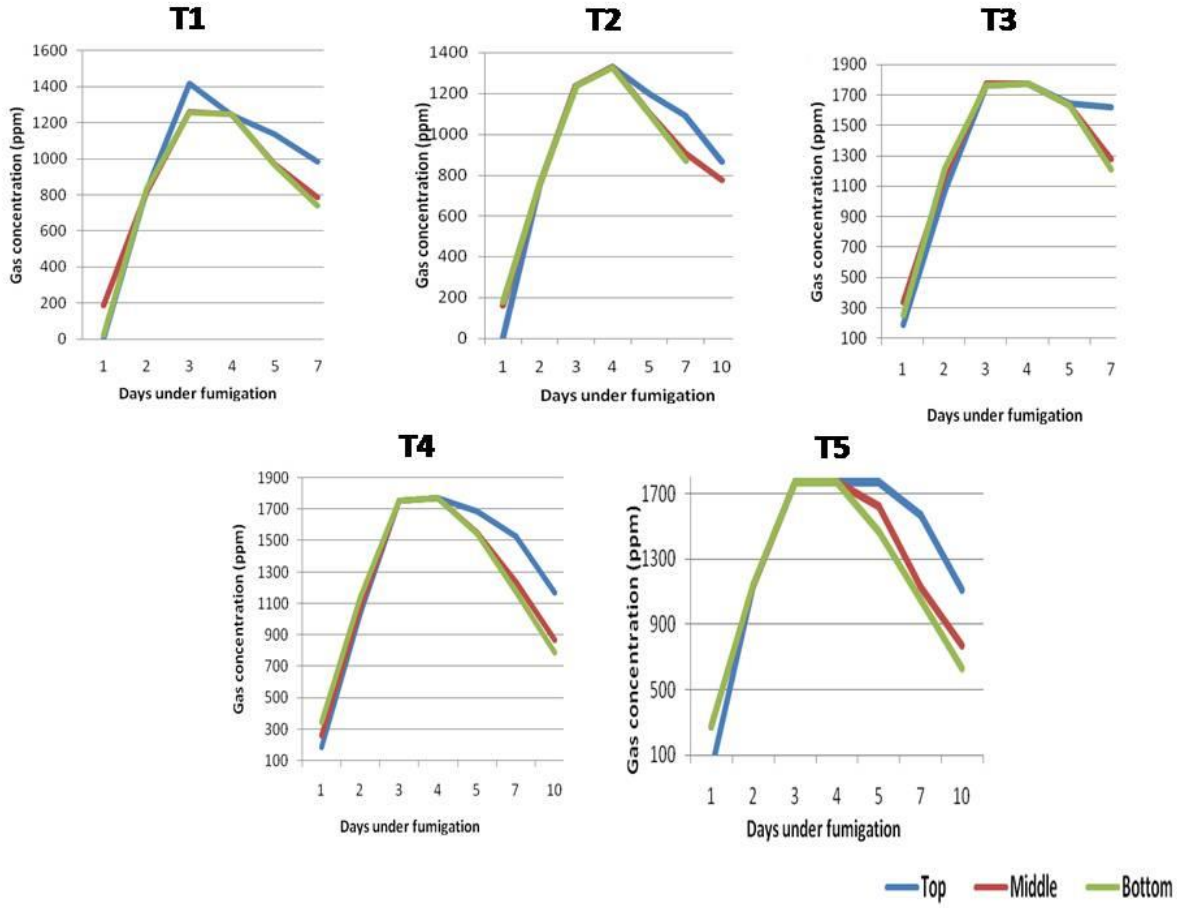

Figure 1 PH_3 concentration studies in Thanjavur CWC (Tamil Nadu).

3.2. Mortality of Insect species with PH_3 tablets different exposure periods

The results regarding mortality of different insect species revealed that mortality was noticed irrespectively in all the treatments. The maximum cent per cent mortality was observed in the treatment with 3T/10D sealed with surgical tape and 3T/10D sealed with sand snakes. The mean mortality of 72.93% was noticed in *Cryptolestes* spp. with 3T/7D sealed with sand snakes. The highest survival of insects was noticed in the untreated check Table 3. Resistant insects must be totally eradicated only using approved rates of PH_3 (Collins, 2006). It was well noticed from the earlier works that the recommended concentration has increased over the years from 80 ppm (Van-Gravel et al., 1992) to 1000 ppm (Annis, 2001) for achieving 100% mortality. To kill resistant insect strains longer exposure is required. However Rajendran et al. (2001) noticed that a few individuals of resistant *R. dominica* and *S. oryzae* survived 7-day treatments in spite of the terminal concentrations exceeding 945 ppm (*R. dominica*) and 885 ppm (*S. oryzae*) at 18-25^{o}C. The occurrence of survivors at longer exposure periods indicates that in addition to extended exposure period, higher dose/ concentration is required for resistant insects. Longer the fumigation time is more effective the fumigation and exposure time to be lengthened for deep penetration in large bulk (Anonymous, 2012). Currently in India black polyethylene 250 µ thickness was used for fumigation. It was found to be cheap and however, upon repeated use the number of holes and damage developed in LDPE was more and it is not durable. In the present study with MLCL and with proper floor sealing the retention of PH_3 was good in all the places of fumigation.

Stacks ready for fumigation with MLCL cover

Aluminium phosphide tablets for fumigation

Fumigation study set up with sand snake sealing

Fumigation study set up with tape sealing

Insect mortality studies

UNIPHOS phosphine monitor

Figure 2 Phosphine fumigation studies conducted in Thanjavur.

Table 2 Average PH_3 gas concentration recorded in warehouses in India.

Treatments		Gudivada Andhra	Morena Madhya Pradesh	Baroda Gujarat	Shajahanpur Uttar Pradesh	Karnal Haryana
T_1	6 hrs	303.44	184.55	29.11	64.11	98.55
	24 hrs	866.78	364.33	548.11	383.55	574.11
	2 days	1085.00	518.77	1118.89	751.00	939.44
	3 days	320.00	605.22	1177.66	995.89	1032.88
	5 days	205.33	663.22	974.77	1235.55	1057.89
	7 days	116.11	698.55	712.33	1226.67	890.77
T_2	6 hrs	204.89	166.44	20.89	280.77	92.44
	24 hrs	903.44	334.22	497.78	637.77	494.33
	2 days	1363.22	458.11	1069.77	907.44	838.66
	3 days	393.33	510.33	1188.11	1131.33	898.66
	5 days	252.55	547.88	741.77	1203.00	916.66
	7 days	159.66	580.00	525.11	1201.88	770.89
	10 days	92.77	509.66	251.89	1022.99	510.77
T_3	6 hrs	309.89	240.77	17.55	109.77	148.00
	24 hrs	1068.77	495.00	779.33	473.22	800.11
	2 days	1300.00	681.67	1731.66	907.77	1234.55
	3 days	339.11	813.11	1698.66	1206.99	1340.44
	5 days	221.33	897.89	1564.11	1585.89	1368.33
	7 days	156.55	985.78	1328.89	1616.00	1151.78
T_4	6 hrs	615.44	283.00	29.11	110.89	165.55
	24 hrs	1514.11	562.66	847.55	538.22	727.22
	2 days	1645.00	764.33	1770.11	1036.11	1162.55
	3 days	431.55	832.66	1781.22	1346.11	1269.89
	5 days	209.66	906.44	1559.00	1781.11	1458.33
	7 days	94.66	1021.22	1162.11	1832.33	1318.44
	10 days	31.78	1013.11	762.33	1755.83	1014.88
T_5	6 hrs	302.88	273.11	30.66	166.00	166.00
	24 hrs	1169.22	552.22	859.89	626.22	626.22
	2 days	437.66	744.33	1829.22	1171.77	1172.55
	3 days	365.77	887.44	1819.55	1535.22	1541.89
	5 days	196.33	976.66	1689.77	1285.00	1285.00
	7 days	191.11	1055.44	1335.00	1434.33	1434.33
	10 days	104.22	1014.55	958.88	1684.11	1684.66
T_6	No fumigation					

3.3. Post-emergence of insect progeny

After fumigation studies, the stacks were aerated immediately at 7th day and 10th day and the insect vials were taken out and observed for mortality. Further the vials were kept for insect emergence. The results obtained showed no-emergence of progeny of any of the test insects for the phosphine.

Table 3 Percent mortality of different insect species.

Treatment	Insects	Percent mortality
2 tablets 7 days	*Sitophilus* spp	100
	Rhizopertha spp.	100
	Tribolium spp.	100
2 tablets 10 days	*Sitophilus* spp	100
	Rhizopertha spp.	100
	Tribolium spp	100
3 tablets 7days	*Sitophilus* spp	100
	Rhizopertha spp.	100
	Tribolium spp.	100
	Cryptolestes spp	72.93
3 tablets 10 days	*Sitophilus* spp	100
	Rhizopertha spp.	100
	Tribolium spp.	100
	Cryptolestes spp	100
3 tablets 10days**	*Sitophilus* spp	100
(Tape sealing)	*Rhizopertha* spp.	100
	Tribolium spp.	100
	Cryptolestes spp	100
Control	*Sitophilus* spp	0.00
	Rhizopertha spp.	0.00
	Tribolium spp.	0.00
	Cryptolestes spp	4.65

**Tape sealing

4. Conclusion

Good quality Multi Layered Cross Laminated fumigation covers along with air tight floor sealing (sand snakes and tape sealing) was found to be efficient in managing the pests. Tape sealing was found to be suitable to maintain the ware house in hygienic condition irrespective of its cost. The retention of phosphine was around 700 ppm, 500 ppm with 2 tablets at 7 and 10 days respectively. It was around 1000 and 900 ppm at 3 tablets at 7 and ten days during the termination of the experiment. However in tape sealing the retention was more than 1000 ppm

even at 10 days. Hundred per cent mortality is achieved in all the treatments with *Sitophilus*, *Tribolium* and *Rhizopertha* spp. In a few places survival of *Cryptolestes* spp. was noticed in treatment with 3 tablets for 7 days.

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