COST EFFECTIVENESS OF UNDER-SHEET AND WHOLE GODOWN FUMIGATION OF BAGGED WHEAT

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ABSTRACT:- Development of resistance against phosphine in stored grain insect pests in Pakistan is the result of whole godown improper fumigation of bagged wheat over the past several years. Trials were conducted in 338 godowns in 8 districts of upper Sindh. Out of these, 169 godowns were selected for fumigation with phosphine inside and under polyethylene sheets, while the others for indoor space fumigation in godowns without covering wheat stack with a sheet. Samples of wheat at the baseline and at two-monthly intervals after fumigation were collected for physical examination. It was observed during the 8 month storage trials that the average moisture content increased by 3%, grain damage increased by 12% and grain weight decreased by 6 kghl^{-1} in whole godown fumigations compared to similar treatment carried out under the cover of polyethylene sheet. The cost effectiveness of the treatments was determined, considering the cost of the materials and labour. It was estimated that a single fumigation treatment in under-sheet stacks was around Rs. 1.05 million less than the whole godown fumigation, even though it involved extra cost of polyethylene (PE) sheet. This cost may be partially recovered by recycling the used PE sheet. This is mainly because whole godown treatments required two to three extra fumigations due to heavy re-infestation of insect pests. Compared to this, sheeted stocks showed no sign of insect activity during the 8 months storage. From the study, it is concluded that under-sheet fumigation of stacks of bagged wheat is a very cost effective and feasible method for protection of stored cereals, and need to be implemented at the provincial and national levels.

Key Words: Wheat; Storage; Fumigation; Under Sheet; Whole Godown; Cost Effective; Pakistan.

INTRODUCTION

The concept of whole godown fumigation, where the indoor space within a godown stocked with stored grains is fumigated for the control of insect pests, has been practiced over the decades in Pakistan and other Asian countries. This method of disinfestation has the potential advantage of controlling insects on the walls, floors and inner roof surfaces, as well as in the grain, thus reducing the immediate chances of re-infestation of the stored commodities. Unfortunately, such fumigations in the past have been carried out in buildings that were not designed specifically for fumigation. As a result, the retention of fumigant gas was usually not sufficiently long enough to provide a complete control of insect pests. Continued exposures to sub-

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lethal concentrations and indiscriminate use of fumigants in whole godown treatments have led to the selection of insect resistance to phosphine. Resistance to phosphine in the different life stages, has also been observed in the storage insect pests (Bell, 2000; Chaudhry, 2000; Collins et al., 2005; Lorine et al., 2007; Pimentel et al., 2007). The recommended exposure periods for phosphine, longer than three days has been recommended for hot climates, mainly aimed at controlling the developmental stages of storage beetles. Other investigations have demonstrated that purpose-built storage buildings can serve effectively as fumigation chambers (Bisbrown, 1992). In Sindh, where existing storage buildings can be sealed to render them reasonably gas-tight, investigations have shown that effective fumigations can be achieved using a multiple dosing method at different time intervals using phosphine. The method involves application of the fumigant in two parts, the second being 24 or 48 hours after the first application. Using this technique, it is possible to prolong the period during which insects are exposed to a lethal concentration of the fumigant, even in buildings where there is some gas leakage (Friendship et al., 1986). Weight loss of wheat due to inadequate storage management and other post-harvest factors at farm and public sector levels have been estimated upto 4 percent (McFarlane, 1989; Abdullahi and Haile, 1991) In addition, there are considerable losses that are caused by insect pests is terms of both quantity and quality of stored wheat in Pakistan. The damage caused by insect pests to wheat grain has been estimated at 10-20% (Ramzan et al., 1991; Khan et al., 2010; Irshad and Talpur, 1993). However, the losses may be as high as 40% for some stored cereals (NRC, 1996). Experiments have shown that such losses cannot be easily reduced in the absence of well-integrated policies and need strategic planning to develop the total system of production, marketing, storage and distribution of cereal grains (Tayler and Boxall, 1984).

The primary pest that damage stored grain are *Trogoderma granarium* Everts, *Rhyzopertha dominica* F, *Tribolium castaneum* Herbst. and *Sitophilus oryzae* L. Their attack is followed by scavengers that feed on grain once the seed coat has been damaged, either mechanically or by another insect (Yadav and Singh, 1994). These are also often the primary pests in milled products such as flour or meal. Examples of scavengers are the red flour beetle, confused flour beetle and saw-toothed grain beetle (Wilkin et al., 1990; Ghizdaru and Deac, 1994; Hyden and Soren, 1987; Desimpelaere, 1996; Abro, 1996; Wong et al., 1996; Suresh and White, 2001; Hulasare, 2003). Secondary pest *Tribolium castaneum* is considered a pest of flour and other milled cereal products and a secondary pest in stored wheat (LeCato, 1975; Hamed and Khattak, 1985, Irshad and Talpur, 1993; Suresh and White, 2001). These pest are usually associated with poor quality grain that is often high in moisture content and moldy. In many godowns and warehouses, there is a rapid turnover or carryover and residual infestation of major storage pests (Rajendran and Narasimhan, 1994).

The combined damage caused by *Rhyzopertha dominica, Sitotroga cereallella* and *Tribolium castaneum* is around 2.5% in wheat. *T. castaneum*

has been found one of major insect species in surveys of stored grains in Pakistan and other countries in the region (Mahmood et al., 1996; Hyden and Soren, 1987; Ghizdaru and Deac, 1994; Khalil and Irshad, 1994; Desimpelaere, 1996; Bandyopadhyay and Gosh, 1999).

The current study was carried out to compare the efficacy of phosphine in whole godown and indoor under-sheet stack fumigation. This study also provides a baseline for procurement of fumigants, pesticides and other necessary material for safe storage of procured wheat in the public sector. The study will thus inform the authorities to formulate a future strategy for cost-effective management of stored grains in Pakistan.

MATERIALS AND METHOD

Experimental Sites

Studies were carried out by Grain Storage Research Institute PARC-Southernzone Agricultural Research Centre, Karachi, during 2002 in districts Sukkur, Ghotki Khairpur, Naushero Feroze, Nawabshah, Larkana, Jaccobabad and Kashmore in upper Sindh. The fresh procured wheat stocks kept in 338 house-type godowns were fumigated two months after arrival. One half of the wheat stocks were stacked inside the godowns and covered under the transparent 0.15mm thick, polyethylene (PE) sheet and the rest used for whole-godown fumigations. The fumigant (Agtoxin @ 3 and 5 tablet m^{-3} in under sheet and whole godowns, respectively was applied. The spray of contact insecticide (100 ml deltamethrine 2.5 EC+10 litre, water 1000 m^{-2} area) was carried out at peripheral areas after every three months under the supervision of trained scientists.

The most common method of sealing sheets at ground level is by tubular sandbags ('sand snakes') which hold down the sheet in contact with the floor. Calculations for whole godown fumigation, polyethylene sheet fumigant and contact insecticides were based on the volume of wheat stacks and godowns.

House Type Godowns (HTG)

The house type godowns generally vary in capacity to accommodate 500-1000t bagged wheat. The godowns are constructed with different type of materials ranging from brick to concrete and stone wall and pre-fabricated RCC slabs to RCC made roofs. The stacking of bagged wheat was separated from the internal pillars particularly the godowns selected for under-sheet in-house phosphine fumigation. The HTGs need proper repair and maintenance for whole godowns fumigation as the structure is highly leaky for one time application of the fumigant. The fractional doses method (application of required dose with 4 separate applications at 24h interval to maintain the lethal concentration and heavy leakage) was used in under sheet and whole godown fumigation.

Grain Sampling

The stocks were visited and inspected and samples were collected from each godown for determination of physical quality characteristics that can indicate insect damage prior to fumigation. In the Sindh province, different HTG with varying capacity are located almost in every district. The samples were collected from all godowns as procedure described by

ISO-9000 prior to fumigation. About 1 kg laboratory represented samples were collected bimonthly from each godown for analysis of physical characteristics such as moisture content (%), test weight ($kghl^{-1}$) and insect damaged grain (%).

RESULTS AND DISCUSSION

The data indicated the fair average quality (FAQ) of wheat stocks were procured and stored by the public sector in various districts of Sindh (Table 1). The data show that the mean moisture content of stored wheat at the time of arrival (2 months after procurement) ranged between 9.0 % and 11.5%. The test weight of wheat range between 75kg and 81kg hl^{-1}. The mean insect damaged grain range was 0.1-2.1%. The data showed that insect infestation starts even at farm gate or at procurement centers. The damaged or weevils grain as a result of insect attack may become contaminated with freshly harvested crop and is sold to procurement center at farm gate (Ahmed et al., 1993). The moisture content in the whole godown fumigated stocks range was 1-3% higher than the sheeted stocks after 8 months storage probably due the high humid climate during monsoon or biological activity in the grain (Table 1). In general, the climatic condition of Pakistan during the wheat harvesting is normally very hot and dry initially but is followed by monsoon period (Ahmed and Shamim, 1995).

The test weight of whole-godown fumigated wheat was 4-6 kg hl^{-1} lower than the sheeted stocks after 8 months storage. It was observed that whole godowns needed re-fumigation after every three months of the storage period. Compared to this, the sheeted stocks may require only one fumigation if properly covered and sealed. This method has been regarded as suitable for developing countries that lack appropriately built grain storage facilities (Friendship, 1989).

The data also indicated the insect damaged grain in the whole godown fumigated wheat was re-infested heavily by insect pests compared to the sheeted stocks which showed a complete control of insect pests and no sign of re-infestation (Table 1). The insect damaged grain in whole godown treatments was 9-12 % higher than at the start of storage, and also when compared with the sheeted wheat stocks in all districts under study. In the sheeted stocks, insect damaged grain even after 8 months storage remained at par with initial storage levels. From the data it was observed the whole godown fumigated wheat was damaged by insect pests. This meant that wheat stored in whole godown needed re-fumigation after every 2-3 months of storage for complete protection.

Comparison of Whole Godowns and In-house Sheeted Stack Wheat Fumigation

Deterioration of stored grain is influenced by physical (temperature, humidity), biological (micro flora, arthropod, vertebrate) and technical (storage conditions, methods and duration) factors (Compton et al., 1993). The data revealed the material required for whole godowns and in-house sheeted cover wheat stocks in the different districts of Sindh Food Department. The total quantity of fumigant required @ 3& 5 tablets m^{-3} was 2133 kg worth of Rs. 1.151 million and 7732 kg worth of 4.199 million in 2002-03, respectively for

Table 1. Physical characteristics of fumigated wheat stored in Food Departments in various districts of Sindh during eight months storage

District	Fumigation	Quality Parameters (Range)											
		Moisture content %				Test weight (kghl^{-1})				Insect Damaged (Mean ± 95% CI)			
		2	4	6	8	2	4	6	8	2	4	6	8
Sukkur	Whg	10-11.3	11.4-12	11-12.5	12-13	76-79	75-79	72-74	72-73	0.78±0.30	3.10±0.76	8.34±01.37	12.97±0.39
	Usht	10-11.5	11-11.3	11.5-12	11.1-11.5	75-80	76-80	75-79	76-79	0.74±0.37	0.99±0.30	1.06±0.33	1.10±0.39
Ghotki	Whg	10-10.9	11.5-12.2	12.3-12.9	12.5-13.3	75-80	75-80	74-78	74-76	0.82±0.55	0.28±074	7.19±1.35	12.03±0.43
	Usht	10-11.0	11.3-11.4	10.5-11.2	11.5-11.8	76-78	76-78	77-79	76-80	0.89±0.24	1.04±0.29	1.43±0.58	1.33±0.46
Khairpur	Whg	9-10.3	10.2-10.9	11.6-12.5	12.4-13	76-79	75-79	74-76	74-75	0.86±0.43	3.43±0.92	9.69±1.66	11.26±1.49
	Usht	10-10.5	10.2-10.9	10.6-10-5	10.4-11	76-79	77-80	77-80	76-79	1.09±0.64	0.82±0.50	1.36±0.50	1.25±0.55
N.Feroze	Whg	9.5-11	11.5-12.2	12.2-12.9	12.7-13.3	75-81	75-76	71-77	72-75	0.89±0.45	2.99±0.73	8.63±0.80	12.76±0.40
	Usht	9-10	10.2-10.9	10.2-10-5	10.7-11	76-79	76-78	77-79	75-79	0.33±0.07	0.99±0.27	1.00±0.35	1.18±0.43
Nawabshah	Whg	10.5-11.0	11.5-12.2	12.6-12.9	12.9-13.3	75-80	76-78	74-75	72-75	0.46±0.29	0.93±0.07	7.59±1.48	11.43±0.78
	Usht	10.3-10.9	11.2-11.7	11.-12	11.4-11.5	77-81	76-80	76-80	75-79	0.97±0.46	1.00±0.30	1.51±0.60	1.36±0.47
Larkana	Whg	10.1-10.86	11.3-12.6	12.2-12.9	12.7-13.3	76-81	75-80	76-80	76-79	0.50±0.69	2.86±0.91	1.17±1.48	12.93±0.53
	Usht	9.3-10.44	11.3-11.4	10.5-11.2	11.5-11.8	76-79	75-80	74-73	73-72	0.67±0.32	0.94±0.33	1.10±0.35	0.91±0.49
Jacobabad	Whg	9.3-10.41	12.2-10.9	12.6-15.5	13.4-13-7	76-79	76-78	76-78	76-79	0.97±0.55	3.24±1.04	7.63±1.32	12.94±0.46
	Usht	10.5-11.1	11-11.3	11.5-11.6	11.1-11.5	76-80	76-78	75-72	74-71	0.45±0.18	0.86±0.38	1.37±0.60	1.28±0.46
Kashmore	Whg	10.3-10.9	11.2-12.2	12.3-12.9	12.8-13.9	75-80	75-80	77-80	77-79	0.69±0.32	4.32±1.08	7.82±1.14	12.56±0.65
	Usht	10.1-10.7	11.3-11.4	10.5-11.2	11.5-11.8	76-80	75-80	74-72	73-70	0.52±0.28	0.99±0.41	1.12±0.38	1.04±0.36

Whg=whole godown fumigation with phophine; Usht=under sheet stacks fumigation with phosphine.

Table 2. Cost studies of whole godowns fumigation in Food Departments in various districts of Sindh

District	No of godowns	Whole Godowns Fumigation cost					Total expenditure (Rs.)
		Fumigation		Insecticide		Sealing & labour charge	
		kg	Cost (Rs)	liters	Cost (Rs)	Cost (Rs)	
Sukkur	15	634	342360	45	31500	22500	396360
Ghotki	10	439	237060	30	21000	15000	273060
Khairpur	27	1439	777060	81	56700	40500	669420
Naushero Feroze	22	921	497340	68	47250	33750	578340
Nawabshah	45	2213	1195020	135	94500	67500	1357020
Larkana	22	1049	590560	66	46200	33000	1935360
Jaccobabad	18	794	428760	54	37800	27000	493560
Kashmore	10	243	131220	15	10500	7500	149220
Grand Total	169	7732	4199380	494	345450	246750	4791580

Table 3. Cost studies in-house stack fumigation of godowns under Polyethylene sheet in Food Departments in various districts of Sindh

District	No of Godowns	In house sheeted stack fumigation cost								Labour Cost	Total expenditure (Rs)
		Polyethylene		Fumigant		Sand bage		Insecticide			
		kg	Cost (Rs)	kg	Cost (Rs)	No	Cost (Rs)	lit	Cost(Rs)		
Sukkur	15	3250	211250	199	10758	2276	9104	30	21000	27000	375922
Ghotki	10	1874	121810	186	100440	2410	9640	20	14000	23700	269590
Khairpur	27	5757	374205	461	248832	5161	20644	54	37800	60000	741481
Naushero froze	22	3858	250770	278	150120	3042	12168	45	31500	37500	482058
Nawabshah	45	6971	453115	455	245376	5365	21460	90	63000	99300	882251
Larkana	22	4451	289315	302	162810	3385	13540	44	30800	38400	534865
Jaccobabad	18	2546	165490	180	97200	2090	8360	36	25200	32100	328350
Kashmore	10	1006	65390	72	329	750	3000	10	7000	12000	126270
Grand Total	169	29713	1931345	2133	1151226	24479	97916	329	2303300	330000	3740787

in-house sheeted stacks and whole godowns. The quantity of required fumigant for whole godowns is thrice higher than sheeted stocks. Fumigation and treatment of grain against rodent and insect damage can be conducted only when it is cost-effective (Appert, 1987). Similarly, the total quantity of contact insecticide Deltamethrine required 2.5 EC. In these districts 329 l and 494 l respectively was used for spray of peripheral areas around the sheeted stacks and whole godowns (Tables 2 and 3). About 29713 kg transparent polyethylene sheet of 0.15mm thickness was used to cover the sheeted wheat in these districts of Sindh Food Department. The most common method of sealing sheeted stacks at ground level is by means of tubular sandbags ('sandsnakes') which hold down the sheet in contact with the floor. The total cost of one time fumigation

incurred about Rs. 3.74 and 4.79 million, respectively for sheeted stack and whole godowns wheat stocks in 338 HTG in 2002-03. The cost of whole godown fumigation is about Rs 1.05 million higher than the sheeted wheat stocks.

Estimated Loss Savings by Adopting Indoor Sheeted Stack Fumigation

The loss savings were estimated by comparing the losses in whole godowns fumigated wheat stocks versus the same treatment under sheeted stacks. About 9-12 % insect damage was recorded in the whole godowns wheat fumigated stocks. The insect damage to wheat occurred mainly due to ineffective fumigation that led to rapid multiplication of residual insect population. Compared to this, a single fumigant treatment of sheeted stocks was not only cost effective but also saved around Rs.1.05 million in 2002-03 (equivalent to Rs. 1.4 million in current value) compared to fumigation in whole godowns that required two to three extra treatments during the same storage period. The recycling of the used PE sheet after fumigation could also recycled to further recoup partial costs. A wheat stock of around 3.1 million tonnes stored for 3-6 months with the probability of an average loss at 2.79%, would incur a loss of around Rs. 782.88 millions in all type of storage structures. Similarly the average losses due to insect infestation to wheat stocks is 1.18 million tonnes stored for 1-2 years would incur 7.9 % loss worth Rs. 695.84 million (Arain et al., 2004). These losses can be saved through effective fumigation under the cover of PE sheets as demonstrated by the current study.

It is therefore, concluded that the whole godown fumigation is highly ineffective due to rapid loss of the fumigant gas from the leaky godowns, and the resultant reinfestation of stored grain due to surviving insect pests. Also, continuation of such a practice may lead to the development of resistant pest populations in the longer term. A single fumigant treatment of sheeted stocks on the other hand provides a means for much more economical and effective treatment. It is therefore strongly recommended that whole godown fumigations of stored grains should be stopped and replaced with fewer but effective fumigations under PE sheet cover. This needs to be adopted as part of a strategy for a cost-effective and safe storage of grains in Pakistan.

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