PN-ABJ-609

Storage Technology Development and Transfer—Pakistan

Report No. 8
October 1991

PROCEEDINGS

BULK WHEAT HANDLING AND STORAGE CONFERENCE

Lahore, Pakistan
June 17 - 19, 1991

KSU
KANSAS STATE UNIVERSITY

FOOD & FEED GRAIN INSTITUTE
MANHATTAN, KANSAS 66506

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INTRODUCTION

BULK WHEAT HANDLING AND STORAGE CONFERENCE

Wheat is the staple food of Pakistan. Per capita consumption is about 120 kg per year. Wheat products account for about 18% of all food expenditures while providing about 60% of the daily caloric food intake. Of the annual production of 15 million metric tonnes, about one half is sold off of farms to be consumed in urban or non-wheat producing rural area.

The Federal and Provincial Governments of Pakistan are heavily involved in wheat production and distribution. The government procures about 70% of the open market supply of wheat and releases it at subsidized rates to flour mills. After harvest, government entities have five to six million tonnes of wheat in storage - including about one million tonnes carry over as a national food reserve.

There is much concern over the government's role in wheat distribution and the technology employed. At present most wheat is collected, stored, and transported in bags. After the harvest, one quarter to one third of the crop is in temporary outdoor storage. Stored wheat is subject to deterioration from inset infestation and inadequate facilities. Storage and handling costs are high in comparison to other countries.

In the mid-1980's, the Government of Pakistan and the United States Agency for International Development (USAID) embarked upon the Food Security Management Project (FSM). The multi-disciplinary effort included research and training in wheat storage and protection, economic analysis of the wheat distribution system and government wheat policies, and rehabilitation of storage facilities. Research into the potential for conversion of bagged wheat handling to bulk handling was later added as a component of the FSM project. the Food and Feed Grain Institute of Kansas State University was selected as the contractor for the Storage Technology Development and Transfer component of the FSM project. While the FSM Project formally ended on 30 June 1991, elements of the project are being continued under other Government of Pakistan and USAID activities.

The Bulk Wheat Handling and Storage Conference, held in Lahore from 17 - 19 June 1991 is in essence a summary of the research conducted and lessons learned thus far under the FSM project. The Natural Resources Institute of the Overseas Development Agency, Great Britain has long cooperated with the Grain Storage Research Laboratory of Karachi, the principal organization conducting the grain storage research under the FSM project. Through this association, several complementary and joint research activities were conducted and their participation in this conference was most appreciated.

Ministry of Food, Agriculture & Cooperatives
(Storage Cell)
in collaboration with
Storage Technology Development and Transfer
Food Security Management Project
The United States Agency for International Development
cordially invite you to attend the

BULK WHEAT HANDLING AND STORAGE CONFERENCE

to be held at the Pearl Continental Hotel, Lahore
on Monday, 17 June, 1991

R.S.V.P.
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(Programme Overleaf)

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PROGRAMME

8:55 a.m.	Guests to take their seats
9:00 a.m.	Recitation from Holy Quran
9:05 a.m.	Welcome Address
9:10 a.m.	Conference Organization and Overview
9:30 a.m.	Introduction of Chief Guest
9:35 a.m.	Inaugural Address
	Tea and Refreshments
	Inaugural Session will follow

Remarks by

Javed Masud, Additional Secretary,
Ministry of Food, Agriculture, and Cooperatives

Chief Guest at the
Bulk Wheat Handling and Storage Conference
Pearl Continental Hotel
Lahore 17 - 19 June 1991

The two subjects of this conference are very important to all of the citizens of Pakistan.

(1) the storage of wheat and
(2) the preservation of wheat in storage

It is gratifying to see that this conference is designed to free us from our past prejudices and complacency and offer real solutions to real problems. The research results to be presented were obtained from actual operating conducted in our godowns and laboratories under practical operating conditions. This is the kind of self-reliance and self sufficiency that is so much needed today.

This conference is also very unique in that for the first time, two international organizations have cooperatively focused on the same problems and will offer their opinions from different perspectives. Thus we will be presented with real choices and be free to chart our own solutions to the problems in grain storage and protection.

Since independence, successive governments have gone all out to provide incentives for greater wheat production to provide for our food security needs. Our efforts have been rewarded with higher production levels nearly every year. This year is no exception. The quality of our wheat is second to none. But unfortunately, we have not been able to deliver to our consumers the full benefits of our successes in production.

While our wheat breeders are using the latest bio-technology to produce new and better varieties, our storage facilities and grain protection techniques have not kept pace. The insect pests that compete with man for the food supply are capable of changing their genetic make up to resist the measures used to control them. The increases in insect resistance to control measures are a result of our adherence to fumigation and chemical control methods that once were effective. In other words, the longer our storage pest control procedures remain the same, the less effective they become. Each passing day of inaction makes the solution to our storage problems more difficult and expensive to achieve.

From the beginning, our nation has added over 200,000 tons of new wheat storage each year, yet we remain short of our needs. More over, some of our earlier built storages are now unserviceable due to shifting populations and wheat production areas. In adding storages, we have experimented with many types of storage facilities. At the present time, we are using six different types of storages for wheat without due regard for the linkages between them.

The basic storage methods we use are little changed since independence. Our basic storage method is the bag, and bags will be with us for many years to come. But we cannot limit ourselves to only one storage method.

Thus today, Pakistan is using conventional bag godowns - some of which date back to the colonial era. In some of our godowns, the bag-cum-bulk storage system is used - a mixture of bags and bulk. We are also using hexagonal bins, which require carrying bags up to 52 steps to the top for pouring into the bins.

We have other silos which are not fully used at the present time. Thus one of the major purposes of gatherings such as this is to assist us in sorting our grain storage and protection needs and priorities. I am happy to note that what will be discussed in this conference in the next two days has been developed in Pakistan for our own needs and conditions.

We must test and find new storage systems that are suitable for our environment and economy. You may have been surprised to learn that the Punjab government has been operating a silo since 1920 that is still in service today. What is needed now is to take the lessons of the past and the technology of the present, and blend them into a system that fully meets our national requirements.

Another difficulty we face is that over the years, we have accumulated a wide variety of wheat storage facilities without adequately considering how to make the best use of them. And after decades of building additional storages, we are still short and end each procurement season with more than one million tonnes in gunjees or outdoor storage. We are using a wide variety of storage types that have been provided with all good intentions by our own and international institutions. What has been lacking is a comprehensive plan for our storage needs in both the public and private sectors.

I must also add that certain past policies of our government have prevented us from taking full advantage of the resourcefulness and ability of our personnel. In particular, the "No Loss" policy places a very heavy burden on our godown managers. They cannot fully comply with the policy and maintain wheat stocks in their best condition. I trust that this conference will also address this situation. There are also other issues such as FAQ standards that also need to be examined. Our managers and godown personnel need guidance and allowances in stock policies that will enable them to function efficiently.

We shall be awaiting your conference recommendations, and wish all of you a full and successful participation in this event.

PROGRAMME

BULK WHEAT HANDLING AND STORAGE CONFERENCE

LAHORE
PEARL CONTINENTAL HOTEL
17 - 19 JUNE 1991

SPONSORED BY:

PAKISTAN AGRICULTURAL RESEARCH COUNCIL
MINISTRY OF FOOD, AGRICULTURE, AND COOPERATIVES
PAKISTAN AGRICULTURE STORAGE AND SERVICES CORPORATION
PUNJAB FOOD DEPARTMENT
FOOD & FEED GRAINS INSTITUTE OF KANSAS STATE UNIVERSITY
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
NATURAL RESOURCES INSTITUTE, ODA, GREAT BRITAIN

BULK WHEAT HANDLING AND STORAGE CONFERENCE

LAHORE, 17-19 JUNE 1991

FIRST SESSION: STORED GRAIN PROTECTION

Monday, 17 June
10:30 -12:45

Presiding: Prof. Mohammad Hanif Quazi, Member (Crop Sciences), PARC

1. Overview of Grain Storage Situation:
   Insect Resistance to Chemical Control Measures
   Dr. Hafiz Ahmed, STDT/Consultant

2. Integrated Pest Management in Bagged Wheat Storage
   Mubarik Ahmed, TARI/Karachi

3. Fumigation of Godowns in Pakistan
   Dr. Derik Halliday, NRI, Great Britain

OPEN FORUM

12:45 - 14:00 LUNCH AND PRAYER BREAK

SECOND SESSION: STORED GRAIN PROTECTION

14:00 - 16:30

Presiding: Umar Khan Baloch, Director of Research (Crop Protection), PARC

4. Phosphene Fumigation of Bulk Wheat in Pakistan
   Sajjad Ahmed, PARC/STDT

5. Persistance of Pesticides in Stored Wheat
   Dr. Zafar Masood, TARI/Karachi

Tea Break

6. Determining Phosphene Dosage for Control of Resistant Insect Pests in Stored Wheat.
   Tariq Mahmood, PARC/STDT

7. Recommendations for Wheat Storage in Pakistan
   Panel of Above Speakers

OPEN FORUM
16:30 Adjourn

THIRD SESSION: BULK HANDLING & STORAGE

18 June
09:30 - 12:30

Presiding: MINFA

8. Bulk Wheat Handling - The Pakistan Experience
   Dr. Ulysses Acasio, STDT
   Shamsher Haider Khan, STDT
   Ibrahim Dasti, Punjab Food Department, Multan

Tea Break

9. Economics of Bulk Handling and Storage
   Dr. Richard C. Maxon, STDT

10. Economics of Bag Handling and Storage
    Dr. Jonathan Coulter, NRI, Great Britain

OPEN FORUM

12:30 - 13:30 LUNCH AND PRAYER BREAK

FOURTH SESSION: BULK HANDLING & STORAGE

13:30 - 16:00

Presiding: MINFA

11. Bulk Handling and Storage: The Public Sector Points of View
    Mukhtar Ali Baig, GM (Field) PASSCO
    Mohammad Sharif, Dep. Secretary, Food Department, Punjab
    Anwar Khan, Dep. Sec. & Dep. Dir., NWFP Food Dep.

OPEN FORUM

Tea Break

12. Bulk Handling and Storage: The Private Sector Points of View
    Wheat Producers Flour Millers
    Transport Contractor Wheat Producers
    Feed Millers

OPEN FORUM
16:00 Adjourn

FIFTH SESSION: BULK HANDLING AND STORAGE

19 June
09:00 - 13:00

Bulk Handling and Storage Demonstrations
PASSCO, Punjab Food Department, PASSCO

Location: PASSCO Storage Complex, Manga Mandi
(Transport will be provided to particpants)

09:00 - 11:00 Demonstrations of Bulk Handling Equipment and Techniques

11:00 - 12:00 Closing remarks and conference summary

PASSCO
Food Departments
MINFA
Private Sector

12:00 - 13:00 Refreshments

13:00 ADJOURN

Bulk Wheat Handling and Storage Conference

Lahore, Pakistan
June 17-19, 1991

Conclusions and Recommendations

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PREFACE

The Storage Technology Development and Transfer (STDT) project, in cooperation with the Pakistan Agrigultural Research Council (PARC), the Pakistan Agricultural Storage and Services Corporation (PASSCO), and the Ministry of Food, Agriculture, and Cooperatives (MINFA) organized a conference on Bulk Wheat Handling and Storage. It was held at the Pearl Continental Hotel, Lahore from June 17 to 19, 1991. Representatives of provincial Food Departments, Flour Mills Association, Pesticide Industry, officials of the United States Agency for International Development (USAID) mission to Pakistan, and two scientists from the Natural Resources Institute (NRI) of United Kingdom (UK) also participated. The main purpose of the conference was to review the work done under the STDT component of the Food Security Management (FSM) project in Pakistan. The NRI scientists presented their research carried out in Pakistan under different projects which related directly to the conference subject.

The first day of the conference was consumed mainly by presentations on the problems relating to the "Protection of Wheat Stored under Pakistan Conditions." On the second and third days, the STDT project studies and field trials on "Bulk Wheat Handling and Storage," were discussed and demonstrated. Lively discussions followed these presentations and demonstrations at the end of each general session.

Speakers on the topic of 'stored grain protection' formed a panel to draw up the main conclusions and formulate recommendations on the subject. Recommendations on the topic of 'bulk wheat handling and storage' have been based primarily on the general consensus at the conference.

Conclusions and recommendations of the conference were recorded separately for each of the above mentioned two topics. These are circulated here for the benefit of individuals and agencies who store large volumes of grain, particularly wheat, in Pakistan.

Protection of Wheat Stored Under Pakistan Conditions

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MAIN CONCLUSIONS

1. Phosphine is a grain fumigant ideal for use in Pakistan. Research work presented at the conference, however, showed the development of varying degrees of resistance to phosphine in some storage pests. The species in which resistant strains have been detected so far are: Trogoderma granarium, Tribolium castaneum, Rhizopertha dominica, and Sitophilus oryzae, all of which are major pests of stored wheat.

2. The panel considered the resistance problem to be serious but still manageable. They felt, however, that the manufacturers as well as users of this gas in Pakistan need to pay greater attention to the problem. This is all the more important because there is no other gas suitable enough to replace phosphine as a grain fumigant in Pakistan.

3. Resistance develops due to the selection for high tolerance in pest populations caused by repeated application of an insufficient dosage. Evidence presented at the conference showed insufficient phosphine dosage in most cases of whole-godown fumigations in Pakistan. Insufficient dosage also takes place when bulk wheat is fumigated by placing Aluminum phosphide (AlP) tablets on the grain surface. The present practices of fumigating whole-godowns, hexagonal bins and bag-cum-bulk system were thus identified as contributing factors responsible for creating phosphine resistant pest strains in Pakistan.

4. Research carried out in Pakistan and elsewhere suggests that control of resistant pest strains is possible through optimizing phosphine dosage. A minimum phosphine concentration of 200 ppm (0.28 mg/l) maintained for at least 20 days provided optimum dosage for the control of storage pests including resistant strains. It was, however, realized that this ideal dosage may be difficult to achieve under all field situations. To contain the problem, however, efforts should be made to achieve this dosage, as far as possible, for all phosphine fumigations of grains in Pakistan.

5. In light of the research work presented, it is concluded that the currently adopted phosphine fumigation practices need improvements. Field trials have shown the following ways of improvement:

- Phosphine fumigation of bagged grains under gas-proof sheets instead of whole-godown fumigation.

- For storage periods of six months or more, the adoption of 'polyethylene enclosure and phosphine fumigation' or 'PEPF' technology (Annexture-I). (The adoption of Polyethylene Enclosure and Phosphine Fumigation (PEPF) technique will be facilitated if field agencies standardize bag stack sizes. This will encourage commercial scale manufacturing of standard sized polyethylene covers in the country).

- Bulk wheat fumigation by inserting AlP tablets at suitable depths in the grain bulk instead of placing them on the grain surface. This gives better gas distribution and retention pattern.

6. Pakistan has recently made good progress in developing manpower, equipment, and other related facilities in the field of wheat postharvest management. It is highly desirable to institutionalize these gains to ensure continuation of progress in this field after the termination of the STDT project.

RECOMMENDATIONS

In view of the problems of pest resistance to phosphine and grain handling mostly in bags, an integrated pest management schedule is envisaged for Pakistan. It includes improved methods of phosphine fumigation to control above 90% pest population and insecticidal spray to eliminate the surviving phosphine resistant individuals.

For the preservation of grain quality during storage, therefore, the following integrated pest management (IPM) protocol is recommended. Ideally, the protocol is suggested for all those involved in the storage of large volumes of grains, both in the public and private sectors, in Pakistan.

1. Preventive Measures

1.1. Grain godowns in the public sector in Pakistan are usually constructed on raised platforms to make them rat-proof. This feature of the godown buildings should be fully utilized. In case a particular godown does not have a rat-proof design, adopt necessary measures to prevent entry of rats in the godowns. Rats in a godown cause not only damage to stored grains, but also interfere with the pest control measures.

1.2. Install screens in doors, windows, and ventilators to prevent entry of birds and bats in grain godowns.

1.3. Apply insecticidal spray to eliminate residual pest populations from a site, particularly the phosphine tolerant individuals. For this, first the premises where grains are regularly stored and handled should be swept. Then apply contact insecticides in the way described below:

i) Before loading with grains, empty the godown building of all the junk or other stores which may be there in a corner for some reason. Clear the outer premises of grass and bushes, if any. Clean the area thoroughly to remove dust and spilled grain etc., which harbour insects. This will mean sweeping the interior walls and ceiling of the godowns also. Collect all sweepings to be taken away from the site for disposal by burying or burning. Likewise clean the premises at the permanent purchase centres, grain markets, silos, bins, and open bulkheads besides the godown sites. The port areas where grains are handled should also be cleaned by sweeping and spraying in the same way. Undertake the site cleanings at least once a year but preferably before the start of every fresh operation.

ii) For spraying, use only recommended contact insecticides. A 1.0% (actual ingredient) water solution/suspension of a mixture of the insecticides permethrin (Coopex W.P.) and pirimiphos methyl (Actellic E.C.) is recommended for this purpose. Always use a power sprayer for application of insecticides in a godown. Apply five (5) litres of the water solution/suspension of insecticides per hundred (100) square metre surface area. Other insecticides or a combination of insecticides can also be used if known to be effective against the storage pest complex of Pakistan. Malathion has become ineffective due to long use and is,

therefore, not recommended for this purpose. (N.B. Do not inhale spray mist. Avoid the spray droplets falling on the naked body parts. Observe all other precautions given in the labels on insecticide containers).

2. PEST CONTROL MEASURES

- Phosphine Fumigations

2.1. Freshly harvested grain stored in a clean and sprayed godown will suffer the least insect damage for about three months without any further pest control measures. However, if grain is not freshly harvested, or is to be stored for more than three months, undertake phosphine fumigation soon after its arrival in the godown.

2.2. Important Considerations

2.2.1. For optimal phosphine toxicity, long exposure to low concentrations of phosphine is more important than high phosphine concentrations for a short exposure period. To kill resistant strains, a minimum concentration of 200 ppm (0.28 mg/l) of phosphine is required for an exposure period of at least 20 days. Try to achieve these conditions in grain fumigations with phosphine, particularly at sites where resistant insect strains are known to be present.

2.2.2. Penetration of phosphine gas into a bag stack of grain is easy and rapid. In large grain bulk, on the other hand, phosphine penetration is slow and difficult.

2.2.3. Thermal expansions and contractions of gases in the free space of a godown occur due to variations in day and night temperatures. This causes high leakage of phosphine gas in whole-godown fumigations. The phenomenon is circumvented in under-sheet fumigations. Under-sheet fumigations are also less expensive because the area volume of enclosure gets considerably reduced due to the exclusion of free space. This reduces the total requirements of AlP tablets.

2.3. Phosphine Fumigation of bagged grain

2.3.1 For safe storage of bagged grains for periods of over six months, PEPF procedure is recommended as detailed in Annexture-1. For less than six but more than three months storage, phosphine fumigation under gas-proof sheets is suggested in the following way:

i) Build stable bag stacks up to maximum feasible height in a godown. Leave sufficient space between ceiling and stack top for movement of workers. Leave about one metre space around each stack as working space for sealing of the gas-proof stack covers with floor of the godown.

ii) Cover the stacks with reinforced (gas-proof) plastic sheets to make a gas-tight enclosure - an essential requirement for successful phosphine fumigation. If the dimensions of a single sheet are not enough to cover the entire stack, join two or more sheets. Join sheets by overlapping them at the ends and folding the ends together. Use suitable clips to hold the folded ends together or keep the folded ends pressed under some

weight such as that of sand snakes, etc. Finally, seal the free ends of stack covers to the floor using sand snakes to make gas-tight enclosures.

iii) For fumigation, calculate the total requirements of AlP tablets at the rate of two tablets per tonne of grain. This should be done without actually opening the bottles, cans or tubes in which these tablets are supplied. Apply half of the total calculated number of tablets in the enclosure. This can be done by lifting the covers a little from the floor at various points to throw in the AlP tablets. Seal the stack again immediately after throwing in the tablets. Make sure that the tablets spread well along the sides between the bags and the covering sheet. Heaping of the tablets at one point could lead to problems. On the eighth day, apply the remaining half portion of AlP tablets in the same way. Be quick and cautious because there will be a high concentration of phosphine gas under the covers on the eighth day. Do not remove covers until after the 20th day of the start of operations. After that period of exposure, the covers may be lifted off the stack for use in other godowns. Covering sheets made of low density polyethylene of 0.2 mm thickness can also be used but their life will be much shorter than the reinforced plastics.

iv) Preferably fumigate all the stacks in a godown at one time. As a precautionary measure, there should be at least two persons present all the time in a godown while working for fumigation. This is essential to ensure help in case one is affected by phosphine gas accidentally.

v) Doors, windows, and ventilators of the godown under phosphine fumigation should be kept closed. This will prevent wind action on the sheet covers and consequential loss of the gas.

2.4. Phosphine Fumigation of Bulk Wheat

2.4.1 For fumigation of bulk wheat in Hexagonal bins, the following procedure is recommended:

i) Before loading wheat, bins should be cleaned if considered necessary on inspection. Each Hex bin can take a maximum of 36 tonnes of wheat but some side bins may be a bit smaller in size. The full sized bin will require 72 AlP tablets at the rate of two tablets per tonne for phosphine fumigation. Do not reduce the number of tablets even if a bin is not filled to its full capacity.

ii) Fumigate bins as soon as loading operations at a site are completed.

iii) AlP tablets should be applied by insertion in the grain and not by placing on the grain surface. The total 72 AlP tablets should be applied in two equal installments with eight days interval in between. The first installment of 36 tablets should be further divided in two equal portions of 18 tablets each. Insert one portion at a depth of about five metres in the grain with help of an AlP tablet applicator (see figures). Insert the second portion in the same way at a depth of one metre in the grain. Place a piece of polyethylene sheet at the mouth of the bin before its closing. On the eighth day, apply the second portion of the dose. For

this, carefully lift the iron lid of the bin without lifting the polyethylene sheet with it. Make a small cut/hole in the polyethylene sheet. Apply the second installment of 36 AlP tablets through this cut/hole in the same way as the first application. This will complete one phosphine fumigation operation.

iv) The bins should not be opened for at least 20 days starting from the first day of the first application of AlP tablets. After this period, the bin may be opened briefly for monthly inspection. The lid should be kept closed for the entire storage period.

2.4.2. For fumigation of wheat in open bulkheads, the following procedure is recommended:

i) Gaps between the floor and the side walls should be plugged by laying a polyethylene sheet at the time of loading. Similarly, all gaps at the corners and near the top of the side walls should be plugged by placing a polyethylene sheet on the inner side. After loading the bulkhead, make sure that gas-proof covers are available or are already placed on the bulkhead. These are required to make the bulkhead gas-tight for phosphine fumigation.

ii) Find out the total wheat tonnage stored in the bulkhead. Arrange for the required number of AlP tablets at the rate of two tablets per tonne of wheat.

iii) Uncover wheat by folding the gas-proof covers without actually pulling them down on the ground. This will save labour and enable the fumigators to re-spread the covers immediately after inserting AlP tablets in the grain. In case wheat has not yet been covered, the gas-proof sheets should be placed in position to cover the wheat immediately after application of AlP tablets.

iv) Measure the top surface area of wheat in the bulkhead and calculate the points for insertion of AlP tablets. The tablets are to be inserted in the grain, about ten (or more) at a point, equidistant from each other. Apply tablets by inserting them with the help of an AlP tablet applicator (see figure). Insert tablets at depths ranging from about one metre in the periphery to slightly deeper parts towards the centre of the bulkhead (see figure of bulkhead).

v) Cover wheat with gas-proof sheets as soon as the operations regarding application of AlP tablets are completed. If the bulkhead requires more than one sheet, join sheets in the same way as described in the paragraph on phosphine fumigation of bagged grain. Make the bulkhead as gas-tight as possible. If done properly, this method will hold phosphine concentration of above 200 ppm in all parts of bulkhead for about 12 days.

vi) Do not use tarpaulin covers on bulkheads for fumigation because these cannot hold phosphine gas.

PEPF - an ideal technique for storage of bagged grain in Pakistan

PEPF is the abbreviation for "Polyethylene Enclosure and Phosphine Fumigation." It is a technique developed by the Grain Storage Research Laboratory (GSRL) of PARC for safe storage of dry grains over long periods.

PEPF involves the sealing of bagged grain in low density, transparent, polyethylene sheets of 0.2 mm thickness and its fumigation with phosphine gas. It is a cost effective and safe technique for the storage of dry grains for periods of over six months. Step-by-step procedures for PEPF application are as under:

i) Plan maximum sized stacks in a godown avoiding pillars, if any. Provide about one metre wide free space around all stack. Mark the base size of each stack on the floor of the godown. Arrange the 0.2 mm thick, low density, transparent polyethylene sheet to wrap around the stacks. The polyethylene sheet is manufactured in tubular form which is then pressed to make two ply sheet rolls for marketing. The required single ply sheet is obtained by making a longitudinal cut from one side. First, make sheets of the required sizes to be used as underlays. Use a continuous band heat sealer for joining sheets. Underlays should be made extending about one metre on all sides from the base size of the stack.

ii) For loading the godown, first spread the underlays made for the stack over the area marked on the floor. Build stable stacks over these sheets up to the maximum possible height leaving enough space between the ceiling and the stack top for the workers.

iii) Tailor polyethylene covers for each stack. Covers should be made to the size of each stack to fit snugly on it. Such covers can be made easily by welding together pieces of polyethylene sheets using a continuous band heat sealer (sealing machine). The cover should be made extending about one metre over and above the height of the bag stack on all sides. When ready, place covers over the stacks without unnecessary delay. The extending portions of the top cover and the underlaid sheet should then be held together one upon the other. Fold these extensions and keep them pressed to the floor using suitable weight such as sand snakes or bricks. Examine covers for damaged polyethylene sheet on all sides. Damage in the sheet (torn or pricked), if detected, should be repaired using a suitable self-adhesive tape. On the completion of all these operations, the stack is now ready for phosphine fumigation.

iv) Fumigate the grain as soon as its wrapping in polyethylene sheet is completed. Do not wait for insect infestation to manifest. For fumigation, calculate the required number of AlP tablets at the rate of two tablets per tonne of grain. Divide the total required tablets into two equal portions for application in two installments. For application, first make small slit openings with a razor-blade in the centre of each side of the stack at a height of about one metre from the ground. Further

divide the half portion of AlP tablets into four equal parts. Throw in one part on each side of the stack through the slit openings. Wearing gloves and using your hand, throw in the tablets on the sides of the stack. Be sure that the tablets spread well inside the polyethylene enclosure (heaping of the tablets at one spot could be dangerous). Close the openings made in the polyethylene cover immediately after throwing in the AlP tablets with adhesive tapes. On the eighth day, remove the adhesive tapes and throw in the second portion of AlP tablets in the same way. Again close the openings immediately with adhesive tapes. This shall complete a single phosphine fumigation operation.

v) Phosphine gas ultimately leaks out of the polyethylene enclosure in three to four weeks leaving no toxic residues in the grain. Do not remove polyethylene covers during the entire period of storage to prevent reinfestation of the grain. Inspect the stored grains regularly. Arrange another fumigation immediately whenever infestation is detected in the enclosure. Make sure that the polyethylene covers are intact on all sides before starting the second or third fumigation.

iv) Doors, ventilators, and windows of the godown building, if any, must be kept closed during the entire period of grain storage. This is essential to prevent entry of birds which may damage the polyethylene sheet. Keeping the doors closed also saves phosphine gas from getting pumped out of the polyethylene envelop due to the impact of wind on it.

vii) Normally, godowns in the public sector in Pakistan are constructed on raised platforms to make them rat-proof. This feature of the godown buildings should be made full use of. In case a particular godown does not have a rat-proof design, necessary anti-rat measures should be adopted to prevent entry of rats in the godowns. Rats, in a godown where grain is stored under PEPF will play havoc with polyethylene wrapping and damage the grains as well.

Bulk Wheat Handling and Storage

SUMMARY & RECOMMENDATIONS FOR BULK HANDLING

Shift to Bulk Handling

The question is not whether or not bulk handling should be used in Pakistan, but only the approach and rate at which bulk handling is to be introduced.

The present experimental scale of bulk handling is too small to be conclusive. Only when entire districts are converted to bulk handling will the true economics and social impacts be revealed. Toward this end, the STDT project will be requested to study the possibility of collecting in bulk from an entire zone of PASSCO.

Context of Bulk Handling and Storage

Bulk handling and storage cannot be introduced and operated in isolation of all other facets of wheat procurement and distribution. Among the issues to be resolved are:

- Form of Storage. Wheat is stored in seven distinct types of storage, bagged in godowns, ganjees and bini-shells; bulk in silos, open bulkheads, and hexagonal bins; and mixed bagged-bulk in bulk-cum-bag storage. Each storage has its own advantages and disadvantages. Bagged storage and handling will be present in Pakistan for many years to come. Up to 50 years may be required for complete conversion to bulk. The goal should be to capitalize on advantages of each storage type and eventually phase out storage which is unsuitable, poorly located, or fully depreciated.

The storage problem of the government can be eased by providing incentives to the private sector. Virtually no dedicated grain storage exists on farms. Private sector storage in mandis and flour mills is limited and unsuitable for longer term storage. The recent widening of margins between procurement and release price has promoted flour mills to procure large quantities from open market during the 1991 harvest season. Private sector producers and processors can develop their own storage if given assurance of stable, long term polices that will permit them to recover their investments and earn a satisfactory margin over time.

- No loss policy. This policy forces godown managers to act in a manner not in the best interest of the organizations who employ them, nor of the wheat entrusted to their area. Only when realistic rules and regulations permit the godown managers to use their training and judgement as to proper care and storage of wheat will the conditions improve.

- Grades and standards. Bulk handling equipment performs better and requires less maintenance when clean wheat is handled. In addition, aeration, fumigation and moisture content are better controlled when cleaner grain is used. Realistic enforcement of grades and standards can provide for cleaner wheat. This issue is closely tied to revisions or abolishment of the no loss policy.

- Wheat pricing. The government's policy is to establish a minimum support price for producers and a uniform wheat release price for benefit of consumers. A subsidy is provided by the provincial governments when cost of procurement, storage and release cannot be covered by wheat release prices. The effect is a rigid pricing system that cannot provide incentives for change in the present procurement, storage, and distribution systems.

Bulk handling will require fewer, more capital incentive procurement and storage sites. Price incentive can be used to induce producers and middlemen to transport wheat in bulk over longer distances. Price incentive can also be used to induce flour millers to convert to bulk handling where bulk suppliers are available.

- Allocation of procurement area. Each year allotment of areas for wheat procurement are negotiated between PASSCO and the provincial Food Departments. This is incompatible with bulk handling. Bulk handling requires long term planning and commitment to placement of facilities, equipment, trained personnel, and arrangements by producers to deliver in bulk. Permanent allocation of procurement areas must be made as soon as possible to ensure that bulk handling can be introduced in an orderly basis.

- Organization and management. Bulk handling systems require intensive management to obtain optimum results. The present system of using contractors for all elements of physical movement and transport is not compatible with institutional ownership of bulk handling equipment and facilities. Revised management structures must be introduced concurrently with the shift to bulk handling.

PASSCO and Food Department personnel must be more actively involved in wheat storage, protection and distribution. The personnel must be more flexible in their work habits and work assignments. Working hours and staffing patterns must be made more flexible during peak seasons. In urban areas, bulk handling can make around the clock deliveries to flour mills possible to avoid traffic congestion.

- Coordination of wheat policies at all levels of government. The federal government has announced as a national policy that free and unrestricted movements of wheat and flour products will be allowed throughout the nation. The provincial governments have also publicly supported this policy. However, districts still impose section 144 restrictions on movement of wheat from their jurisdictions and, at times, the provincial governments reimpose section 144 restrictions for various reasons. The private sector is reluctant to invest or use their initiative in constructing storage or acquiring stocks for long term storage.

- Enrollment of private sector. Limited tests indicate that the flour milling industry can achieve a savings of up to Rs 90 per tonne by conversion to bulk handling. Flour mills wishing to take advantage of the savings potential should cooperate with departments for loading and unloading of bulk storage. By sharing a part of their savings, the flour

mills can avail of bulk handling at a much faster pace than by waiting for the food departments to provide the facilities.

RECOMMENDATIONS

1. A long range policy developed for conversion of bags to bulk handling. The policy would state objectives in terms of reducing costs, modernizing agriculture and promotion of industry and self-reliance. Initial time tables would be set to avoid disruptions and dislocations among producers, laborers, and the private sector.

   The initial goal would be to use existing bulk facilities to the maximum extent, and avoid rebagging of wheat once is it offered for sale or stored in bulk form. Where facilities are to be expanded or replaced, bulk handling would be replaced.

   Standards for bulk handling should be introduced, so that ease of interchange can be facilitated, and that local industries can be encouraged to manufacture bulk handling equipment. Such standards would include minimum capacities in tonnes per hour, dimensions for dump pits, clearances between transport equipment and unloading devices, clearance and turning radiuses for major bulk handling facilities, and safety equipment for facilities and bulk handling personnel.

2. Larger scale tests of bulk handling be conducted for testing bulk systems on a zonal basis in PASSCO or district in the Food Departments.

3. That current policies be revised to provide incentives for short and long term development of bulk handling. The no loss policy be revised or eliminated to permit reasonable adjustments in quantity and quality of wheat inventories to handling losses, cleaning, blending, or other operations possible with bulk handling.

   Flexibility in prices be permitted on an experimental basis to determine producer and flour mill response to bulk handling in terms of (1) collection and delivery in bulk over longer distances and concurrent elimination of local procurement centers, (2) incentives for quality enhancement and more effective use of wheat by-products, and (3) cost sharing between public and private sector for conversion to bulk handling.

Bulk Wheat Handling and Storage Conference

Lahore, Pakistan
June 17-19, 1991

Impressions
and
Remarks

Barcoded Resource Stamp

Grams : "HILFLOUR"

Phones Mills : 81155
81055
Res. : 32431

Hilal Flour & General Mills Ltd.,

Registered Office ;
INDUSTRIAL ESTATE,
MULTAN.

Ref. No. _____ *Dated* _____

TO WHOM IT MAY CONCERN

It is submitted that we The Hilal Flour & General Mills Limited, Multan have received 805,000 Kgs of wheat in Bulk from Food Deptt; Multan, under STDT Project of US AID Scheme for the period from December 20, 1990 to January 10, 1991. This is a time saving, labour saving and money saving scheme for both the Company and the Food Deptt. We can save Rs. 8/- as the cost of bag, Rs. 0.50/- as loading of a bag at the godown, Rs. 0.50/- as unloading of a bag at the mills and Rs. 0.25/- as interest saving on bag cost. This is an excellent scheme. We are ready to purchase our own Bulk equipments and also to modify our grain receiving pit as recommended by the STDT team on its visit. We request that this scheme may be continued in future for better Flour Milling prospects.

for HILAL FLOUR & GENERAL MILLS LTD

(MIAN ANIS AHMAD SHEIKH)
Chief Executive

MR. IDREES

The Chairman
honourable Guests and Participants

This is a matter of great honour for me to represent Pakistan Flour Mills Association Karachi Sindh in this Seminar.
Iam also thankful to the Organisers of this seminar for providing me the time to tell the participants our impression or Bulk handling.

We are very pleased to know that STDT had arranged a very successful demonstration of bulk delivery of wheat for the punjab flour millers with the assistance of Punjab Food department. We have discussed the issue with Punjab flour millers. This is really a useful scheme for the Govt as well as for the Flour millers. We do have tremendous savings in bulk handling system.

we request the STDT to please organise the similar demonstration of bulk handling at Karachi for the benifit of Public and Private sector.

We are closely associated with the Provincial food departments and looking forward the greatest development and mechanisation in the country under STDT/USAID program.

Thanks and regards

Mahmood Hasan
vice chairman Pakistan
Flour Mills association
Karachi - Sindh.

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Bulk Wheat Handling and Storage Conference

Lahore, Pakistan
June 17-19, 1991

Papers Presented

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THE PROBLEM OF RESISTANCE TO PHOSPHINE IN INSECT PESTS OF STORED FOODGRAINS IN PAKISTAN - AN OVERVIEW

By
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Babur, the first Mogul emperor who invaded the subcontinent in 1525 AD, was surprised to see the people here eating grain (Roti) with grain (Dal). To him, grains alone could not possibly make a wholesome meal for the Homo sapiens. Perhaps he was right. Yet, for the past many centuries, grains have remained an almost exclusive item for meals for many people, races, and creeds in this part of the world. A common man in Pakistan still derives about 70% of his requirements of calories and proteins from food grains. Preservation of grain quality therefore, means caring for the health of the nation.

To feed her teeming millions, it has been the top most priority with every government in Pakistan to increase the production of food grain. Their efforts have borne fruit. Pakistan's present (1989-90) annual production of food grains is about 19.45 million tonnes of which about 14.32 million tonnes (74%) is wheat, 3.22 million tonnes (16%) milled rice, 1.18 million tonnes (6%) of maize and about 0.73 million tonnes (4%) are pulses. A major portion (about 70%) of total production is held by farmers for their own consumption and seed use, etc. Main buyers of farmer's surplus are the public sector agencies like PASSCO, Rice Export Corporation of Pakistan (RECP), and the provincial Food Departments. On the average, about a million tonnes of rice are purchased for export and a similar quantity of wheat is imported to supplement local production. About four million tonnes of indigenous wheat are also purchased from production surplus areas to supply the urban and production deficit areas during the year. At peak time, the public sector in Pakistan may be holding about six million tonnes of food grains. This leaves less than a million tonne (about 5%) of the total production for the private sector to deal with. At least for the present, therefore, handling and storage of large volumes of grain is primarily a public sector activity in Pakistan.

Grains are attacked by a variety of insects during storage. Development of insect infestation in stored food grains reduce their nutritional, market, and seed values and, in the case of heavy infestation, even the weight of the stored commodity. To control insects, several methods and techniques are available.

A write-up of the presentation made at STDT Conference on 'Grain Handling & Storage' at Lahore, June 17-19, 1991.

For large grain volumes, the presently prevalent methods for providing protection against insects are the application of:

- Protectants - admixing of synthetic insecticides, inert dusts, etc., with grain.

- Aeration - to bring down grain temperature and its moisture content.

- Modified Atmospheres - creating an atmosphere of carbon dioxide or nitrogen in a sealed storage space.

- Fumigation - releasing toxic gases in a sealed storage space.

Because grains in Pakistan are handled and stored predominantly in bags, admixture of protectants to large volumes is not, at least for the present, economically feasible. 'Aeration' and 'Modified Atmospheres' are the technologies which also do not hold much scope because both the techniques require a high level of skill and capital investment, which are both scarce in poorer developing countries. Like other developing countries, therefore, Pakistan also finds it convenient to fumigate grain with toxic gases for the control of insect infestations.

For the past about thirty years, fumigation, particularly at the level of central storage (large volumes), has been undertaken almost exclusively with either phosphine or methyl bromide. Relative cheapness, ease in application, ready availability, least of residues, and involvement of almost no safety & application equipment etc., are some of the points which have favoured phosphine to the extent that it has virtually replaced methyl bromide as fumigant in many countries. The ability in insects to develop high tolerance (resistance) to phosphine has, however, created problems in its use in Pakistan in recent years. The detection of high levels of phosphine resistance in Rhizopertha dominica and Tribolium castaneum from Pakistan (Taylor, 1986; Taylor and Halliday, 1986) caused worries because there is, at present, no substitute grain fumigant available having properties as suitable for the Pakistan situation as phosphine. The STDT project, therefore, gave priority in its research programme to develop the technology for the management of phosphine resistance in stored grain insect pests in Pakistan. This paper presents an overview of this and some earlier research in this area.

Essentials of fumigation.

Before proceeding any further, it will be useful to explain by reiterating some of the basic factors involved in the fumigation operations. In this context it is important to know that:

- A Fumigant is a chemical which, at the normal conditions of temperature and atmospheric pressure, will exist in gaseous state. It differs from aerosols, fogs, mists, and smokes all of which are suspensions of minute particles of liquids or solids dispersed in air.

- Fumigation is the process of establishing an environment containing a

fumigant in an enclosed (storage) space in which the concentrations of the fumigant are high enough and are maintained for a period long enough to be lethal to all pests (insects, rats, bats, birds, etc.) in all their developmental stages (eggs, larvae, pupae and/or, adults) and forms (resistant and/or susceptible strains), infesting that space.

Dose and dosage, have a somewhat arbitrary distinction.

Dose generally refers to the unknown quantity of fumigant which the animal absorbs from its gaseous environment. Dosage, on the other hand, refers to the process in which a measured amount of fumigant is introduced in the environment from which a dose is absorbed by the pest progressively over a period of time of exposure to that environment.

Dosage in fumigation is, therefore, generally expressed as the product of concentration (C) of the fumigant and the time (t) of exposure or the Ct product. The relationship presented in its simplest form is:

$$C \times t = K$$

It thus follows, that a constant K (say a level of kill) can be achieved by changing either the concentration (C) or the time of exposure (t). Ct product of 166 mg/hr/l of methyl bromide (CH_3Br) is required for a 99% kill in Tenebroides mauritanicus. This may be achieved in any of the following ways:

Concentration (C) of CH_3Br (mg/l)	Exposure time (t) in hours	Ct product mg/hr/l
83	2	166
55.3	3	166
41.5	4	166
33.2	5	166
23.7	7	166
16.6	10	166

(From FAO's Manual of Fumigation for Insect Control, Monro 1969)

The above relationships, however, do not fit with all fumigants. A more general relationship between concentration and time is of the form:

$$C^n \times t = K$$

where K is again representing a constant level of response such as LD_{99} (lethal dose for 99% of the pest population). The exponent n is the toxicity index that describes the specific toxicity relationship between a fumigant and a pest species and/or the developmental stages of the pest species. The importance of n in practical fumigations lies in knowing the general magnitude of n for the fumigant being used and the pest species being treated. For example, the values

of n for phosphine are mostly less than one, which indicates that exposure time is more important for the outcome of fumigation than concentration. For fumigants for which the value of n is generally greater than one, as is the case of methyl bromide, it would be more effective to increase the concentration than to increase the time of exposure.

Phosphine dosage for grain fumigation.

Phosphine has now been used as a grain fumigant for more than 30 years. It seems however, that the significance of exposure time vis-a-vis the toxicity of phosphine was not adequately understood in the early days of its use as a grain fumigant. FAO's Manual of Fumigation for Insect Control (Monro 1969), for example, first prescribed dosage for bulk grain of 90 AlP tablets/1000 bushels (about 2.5 g/m^3) for an exposure period of three days for temperatures of 21°C and above. Later, FAO (Bond 1984) changed this to 1-2 g/m^3 or 35-70 AlP tablets per 1000 bushels for a minimum exposure period of five days at 21-25°C and four days at 26°C and above. A dosage rate of 1.5 g/m^3 and exposure period of seven days at a temperature above 25°C was recommended for Australia by Winks et al. (1980) as members of the Entomology Committee of SCA. The European Plant Protection Organization (EPPO) fumigation standard 18 (Anon., 1984) specifies minimum exposure periods varying from three to 12 days, depending upon the species, for a dosage of 1 g/m^3 for good conditions and 2-3 g/m^3 in leaky conditions. Mills (1986) has however, expressed skepticism over the three to five day exposure period, specified for the dose rate of 1 g PH_3/m^3, to completely kill the coleopterous pests including Tribolium castaneum and Rhizopertha dominica. He (loc. cit.) is also not sure that the increased dosage rate of 2-3 g/m^3 will be adequate to cover the most leaky conditions. A number of authors at the GASGA seminar (1986), particularly Bell (1986), emphasized the need to apply phosphine over as long an exposure period as possible instead of using a high concentration for short periods. Probably due to this emphasis, a panel of experts has recently (Anonymous 1989) recommended a phosphine dosage rate of 1.5 g/m^3 with a minimum exposure period of 20 days for temperatures above 25°C for the ASEAN region. This brief account indicates the emerging importance of time of exposure in phosphine fumigation.

Development of resistance to phosphine in insect pests of stored grains.

It is natural with animals that they develop resistance to toxicants after some progeny are generated under selection pressure caused by low dosage of the toxicant in their environment. Low dose kills the susceptible individuals while those having high natural tolerance survive. The surviving individuals attain genetic purity for still higher tolerance if the selection pressure is continued resulting in the ultimate development of the resistance strain. Another important aspect of the resistance phenomenon is that it is both species and toxicant specific. This means that some pest species are able to acquire resistance against some toxicants more readily than others. Besides, a species having acquired resistance against one toxicant may exhibit cross-resistance against other toxicants as well. This is precisely what has been happening in the case of phosphine fumigations where low dosage rates were applied in various ways in almost all parts of the world for many years.

Winks (1986) as well as Mills (1986) has mentioned that the first case of

phosphine resistance was detected by Monro et al. (1961) as cross-resistance following laboratory selection of Sitophilus granarius with methyl bromide. The FAO global survey in 1973 on susceptibility of stored grain pests to pesticides showed an increased tolerance to phosphine in 10% of the total strains tested as against only 5% to methyl bromide (Champ and Dyte, 1976). Borah and Chahal (1979) reported the first field failure of phosphine fumigation in the Indian state of Punjab due to the development of resistance in the eggs and larvae of Trogoderma granarium. Tyler et al. (1983) reported failure of phosphine fumigation in warehouses in Bangladesh. Mills (1983) later confirmed through laboratory tests that the failure was due to the development of resistance to phosphine. Alam et al. (1984) reported cases of whole-godown phosphine fumigation failures at Landhi and Bin Qasim near Karachi. They (loc. cit.) attributed these failures to the leakiness of the warehouse (godown) buildings including 'Binishells.' Laboratory tests of Rhizopertha dominica and Tribolium castaneum collected from these sites later revealed the development of resistance to phosphine in these species (Taylor, 1986). Mills (1986) has reported the incidence of insect strains containing resistant individuals collected from inland sources in the UK. Taylor (1989) has listed a number of countries from the continents of Asia, Africa and South America (only Brazil) from where phosphine resistant strains of storage pests (only coleopterous beetles) have been recorded. Development of low levels of resistance to phosphine in Rhizopertha dominica, Tribolium castaneum & Cryptolestes sp. have also been detected in Australia (Winks et al., 1989).

Research on phosphine resistance management in Pakistan.

Realizing the gravity of the situation, the STDT project, in collaboration with the Natural Resources Institute (NRI) of the UK, sponsored research in the Grain Storage Research Laboratory (GSRL) of PARC to monitor resistance to pesticides, including phosphine, in major stored grain pests in Pakistan. Results (Alam et al., in press) showed various levels of resistance to phosphine in the adults of Rhizopertha dominica and Tribolium castaneum and the full grown larvae of Trogoderma granarium collected from various, (but not all), places in the country. Of all the species tested, adults of Sitophilus oryzae were found to have developed the least resistance to phosphine (Alam et al., loc. cit.).

Enough evidence has appeared since 1980 to suggest that the resistance to phosphine is developing due to poor fumigation techniques being used in developing countries (GASGA Seminar 1986). In order to understand the situation in Pakistan, some of the phosphine fumigation (of whole-godown) operations of the provincial Food Departments (FDs), RECP, and PASSCO were monitored at various places by researchers of the GSRL using PARC funds and also under the STDT project. Phosphine retaining capacity observed in some of these godowns is shown below:

Particulars of the godown	Date of fumigation	Dose g/m3	Days for which gas was retained
Binishell No. J-3 of RECP at Bin Qasim	Dec. 4, 83	1	3
House-type No. 10-A of RECP at Bin Qasim	"	"	"
House-type No. SGG-III (6) of Sind FD at Landhi. Cap. 18,000 MT	Feb 4, 84	"	"
PASSCO type godown 1 of Punjab FD at Multan	Dec 9, 88	"	6
PASSCO type godown 2 of Punjab FD at Multan	Aug 21, 88 Feb 7, 89	1.5 + 1 1	5 5
PASSCO Godown No. 16 at Manga	Sep 1, 88 May 11, 89	1 1	7 6
PASSCO Godown No. 4 at Manga	Aug 6, 89	1	3
PASSCO Godown No. 14 at Manga	Aug 8, 90	1	5
PASSCO Godown No. 17 at Manga	Sep 1, 88 May 11, 89	1.5 + 1 1.5 + 1	8 7
PASSCO Godown No. 5 at Manga	Aug 6, 89	1.5 + 1	8

It is clear from these observations that Binishells and the large sized House-type godowns of the Sind Food Department and RECP located at Karachi are very leaky and, therefore, unsuitable for whole-godown phosphine fumigation. Alam et al. (1984), in fact, detected live insects in these godowns immediately after the completion of fumigation operations. The PASSCO design of House-type godowns is generally better but there are some godowns, for example Godown No. 4 at Manga, which are also very leaky and, therefore, unsuitable for whole-godown fumigations. Recent IPM research under STDT (Ahmed et al., 1991) has shown that despite repeated fumigations, losses due to insect infestations take place on all whole-godown phosphine fumigations.

Since adequate exposures cannot be achieved in whole-godown operations, Alam et al. (1984) recommended that the practice should be abandoned in favour of under sheet phosphine fumigation. Friendship et al., (1986) also proposed that "the simplest approach to ensuring that commodities fumigated with phosphine in Bangladesh and Pakistan are given adequate exposure periods to lethal concentrations of gas is to replace the practice of whole-godown fumigation with that of fumigation under sheets." Recent IPM research carried out under STDT has shown that even under sheet phosphine fumigation has failed to achieve complete control of wheat storage pests in Pakistan (Ahmed, et al., 1991). Gas concentrations of

more than 200 ppm (0.28 mg/l) of phosphine and exposure time of up to 12 days failed to provide complete protection in bagged wheat (Ahmed et al., loc. cit.). What then is the adequate exposure time for phosphine gas to fully control the storage insect pest complex of Pakistan? For an answer to this vital question, studies were initiated at the STDT Centre, Lahore, using plastic drums as fumigation chambers, to expose mixed cultures of storage pests collected from various (central) wheat storage sites. The maximum exposure time tested in these drums was 14 days. Phosphine gas was introduced in each drum to obtain an initial concentration of about 500 ppm which dropped to about 250 ppm in 14 days. Mortalities are recorded every day starting from the third day, by opening one drum daily. Results obtained so far are summarized below:

Pest Species	Days required for complete kill	Storage site to which the strain belonged
Trogoderma granarium	up to 03	Jhang, Jhelum, Sehala and Islamabad-2
	04 to 07	Bahawalpur, Murdekey, Badami Bagh, Sargodha, Quaiadabad, Rawalpindi, and Islamadad-1
	08 to 11	Faisalabad, Hasilpur, Manga G-4 and Jhalarian
	12 to 14	Manga G-9 & Dunyapur
Tribolium castaneum	up to 03	Murdekey, Islamabad, Rawalpindi, Jhelum and Sargodha
	04 to 07	Manga (9) & Dunyapur
	12 to 14	Manga (4) & Hasilpur
Rhizopertha dominica	up to 03	Manga (9), Murdekey, Faisalabad, Jhang, and many other places
	04 to 07	Islamabad-1, Manga (4) and Quaidabad
	up to 11	Hasilpur

Other pests species, namely *Sitophilus oryzae* and *Cryptolestes ferrugineus*, were also found at some places but both the species were susceptible and died within three days. Details of this work will be presented by Mr. Tariq Mahmood and others.

The above results showed that phosphine concentrations of more than 250 ppm for an exposure period of more than 14 days were the essential requirements to control the whole of wheat storage pest complex which included the more tolerant egg and pupal life stages as well as the phosphine resistant strains. These

essential conditions cannot possibly be met in whole-godown fumigations where phosphine gas can be retained for a maximum period of about eight days even with multiple dosing (see the data given above). What could then be done? Fortunately, for the protection of bagged grain, the "Polyethylene Enclosure and Phosphine Fumigation" or "PEPF" technique (Ahmed, et al. 1987) allows the extension of exposure time to any desired extent. All one has to do is to fractionalize the total required dose and go on adding AlP tablets in the polyethylene enclosure at suitable intervals. The latest STDT recommendation for the phosphine fumigation of bagged grain stored inside the godowns, therefore, is to enclose the bag stacks in polyethylene envelops to make gas-tight closures and then fumigate by applying a dose of two AlP tablets per tonne of grain in two equal fractions (i.e. one tablet/tonne in each case) with one week's interval in between. In this way, a phosphine concentration of more than 200 ppm can be retained for more than 20 days exposure (unpublished observation).

Besides the whole-godown fumigation of bagged grain, phosphine fumigation is also undertaken under tarpaulin covers to protect wheat in the open in 'Gangees'. This surely is a bad practice and should be abandoned. The PASSCO practice of fumigating bag-cum-bulk wheat in house-type godowns by surface placing of AlP tablets was monitored. It has been discovered that in this way, not enough phosphine gas reaches the bottom portions of the wheat bulk. Efforts were made to introduce innovative improvements by placing a portion of the dose inside the grain mass. There was some improvement in gas distribution but the essential requirements of at least 200 ppm phosphine concentration in all parts of the godown as well as the grain mass, for exposure period of at least 20 days, could not be achieved. Detailed progress of this work will be presented by Mr. M. Sajjad Ahmad.

The STDT project also undertook extensive studies for the improvement of phosphine fumigation of bulk wheat stored in Hex bins and open bulkheads by FDS and PASSCO. By dividing the dose and the insertion of AlP tablets at suitable depths in the wheat bulk, gas distribution as well as its retention in all parts of Hex bins improved considerably (Ahmad et al., 1990). By repeating the fumigation in the same way after one week, the desired phosphine concentration of over 200 ppm for an exposure period of at least 20 days can be achieved. In the open bulkheads, a similar improvement was achieved in the same way but repetition of fumigation at a week's interval without losing the gas already present in the wheat bulk seems difficult. Details of this work are also being presented by Mr. M. Sajjad Ahmad. Studies were also undertaken under STDT to determine the persistence of some common grain protectants under simulated conditions of Pakistan. Results show permethrin to be the most persistent compound. The details of this work will be presented by Dr. S. Zafar Masud.

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COMPARATIVE COST EFFECTIVENESS OF FOUR INTEGRATED PEST MANAGEMENT METHODS FOR STORAGE OF BAGGED WHEAT IN LAHORE AND MULTAN

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ABSTRACT

Four Integrated Pest Management Protocols for protection of stored wheat in bags were tested in Lahore and Multan for evaluating their cost effectiveness. These IPM protocols included the laid down practice of the Punjab Food Department (P-1); Multiple dose fumigation with spraying of peripheral bags (P-2); Phosphine Fumigation under Polyethylene Enclosure (PEPF) (P-3); and control or monitoring of actual agency routine practice (P-4). In Multan storage loss during treatment period was highest in control (P-4) followed by PEPF (P-3), Multiple dose fumigation (P-2), and the recommended practice (P-1). The total insect load at dispatch and the quantity lost and its value also showed the same pattern. Net cost (total expenditure + value of loss) was highest for agency controlled followed by Multiple dose fumigation, PEPF, and the recommended practice in that order. In Lahore due to relatively less insect infestation magnitude of loss was much less. The highest storage loss was recorded in Multiple dose fumigation followed by recommended practice, control, and PEPF. The total insect density at dispatch was highest in the recommended practice followed by control, Multiple dose fumigation, and PEPF. However, the maximum percentage increase in number of insects at issue over arrival was found in control followed by Multiple dose fumigation, PEPF, and the recommended practice. Net cost was highest in Multiple dose fumigation followed by the recommended practice, control, and PEPF. None of the protocols at both the sites was able to achieve a complete control of insects as they have developed high level of resistance against phosphine. However, the one which provided for the under sheet phosphine fumigation (PEPF) appeared to be comparatively most qualified for use by public sector agencies.

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INTRODUCTION

Public sector storage losses of wheat in Pakistan are reported to be as high as 3.6% (Baluch et al. 1986) which is worth about Rs 430 million at 1989-90 price rates. The basic reason for such high losses in the country are improper storage practices that include lack of sanitary conditions, leaky and poorly maintained godowns, acceptance of sub-standard and infested wheat, inadequate and improper use of contact insecticides and fumigants, and the lack of trained manpower (Ahmed et al. 1986, 1987, Ahmed and Shaukat 1989). This has resulted in development of highly resistant strains of insect pest species that have become difficult to control (Friendship et al. 1986, Taylor 1986).

The increasing limitations in insecticidal application have given rise to the alternative concept of Integrated Pest Management. This involves efforts to develop compatible systems of insect management through chemical, physical, biological, and other alternative methods applied singly or in combination and keeping in view the storage environment and other ecological conditions to achieve the desired results. The systems are thoroughly tested for their effectiveness and cost economics. Therefore, four packages of integrated pest management were separately investigated in Lahore and Multan. The treatments include the laid down procedure for pest management in code of practice for the Punjab Food Department, two modern treatment procedures including Multiple dose fumigation and PEPF technique for storage and the procedure that is actually being practiced at the storage complexes.

MATERIAL AND METHODS

Experiments were conducted in Lahore and Multan in PASSCO - house type godowns each of 1110 tonnes storage capacity in bags. The size of each godown was 30.5 x 18.9 x 5.6m. Four stacks were made in each godown, each stack was approximately 14.26m in length and 8.42m in width and 14 bags in height. Each stack thus contained approximately 250 tonnes of wheat. Stack size and pattern were kept uniform at all the sites.

At arrival all the bags in each stack were sampled by means of a spear. For this purpose a primary sample of about 250g was obtained from each bag by probing at three different points to make up a separate composite sample for each of the stacks. The composite samples obtained from different stacks were kept in separate jute bags internally lined with polyethylene. The composite sample of each stack was further divided by a Boerner type divider to obtain three composite samples of about 1.5 Kg each for laboratory analysis. Similar sampling was conducted at the time of dispatch or issue of stacks which in case of Multan was 12 months and varied from nine to 15 months for different protocols in Lahore (cf. Table-4). The laboratory samples of arrival and issue were analyzed in a laboratory and compared individually for determining the weight loss, insect infestation and the changes in the physical quality characteristics of grains, etc. For recording moisture content of grain the Burrow Digital Moisture Computer Model 700 was used.

The following four treatment protocols were applied and compared for their effectiveness and costs:

i) Present system of quality maintenance as laid down by PFD (P-1)

The godowns were cleaned and sprayed with Malathion 57 percent EC at the ratio of 1:25 before stacking on the walls, floor and roof. Soon after stacking, the first fumigation was carried out in Multan and Lahore in August and September 1988, respectively with aluminum phosphide (AlP) tablets at a dosage rate of one tablet per cubic meter. In Multan the second phosphine fumigation was carried out in December 1988 due to the development of insect infestation, whereas in Lahore, the second fumigation was conducted in May 1989.

ii) Multiple dose fumigation and peripheral spraying of bags with Actellic (P-2)

The godowns subjected to this treatment were made airtight by mud plastering their doors and ventilators and plugging the possible gas leakage points. The godowns were then fumigated with AlP tablets placed in fractionate doses i.e. an initial dose of 1.5 tablet per cubic meter followed by another dose of one tablet per cubic meter on the third day of initial application. After the disappearance of gas, the four stacks were sprayed on their exposed surfaces with Actellic 50 percent EC as per prescribed dose by the manufacturer. In Multan, the first treatment was carried out in August, 1988 which was followed by a single dose fumigation and insecticide application in February, 1989. In Lahore two multiple dose fumigations were carried out, the first in September 1988 and the second in May 1989.

iii) Polyethylene Enclosure and Phosphine Fumigation (PEPF) (P-3)

The individual stacks were enclosed in polyethylene sheets (0.2mm thick, low density and transparent). Polyethylene underlays and caps were prepared according to the size of stacks by heat-sealing the marked sheet. The underlays were laid before stacking on the floor. The stacks on completion were enclosed in polyethylene caps prepared for this purpose by heat-sealing the marked sheets as per stack size and shape. The cap and underlay of each stack were heat-sealed together to make the enclosure air tight. For the purpose of fumigation, incisions were given in the polyethylene sheet and AlP tablet at the rate of 1 tablet per cubic meter were placed on top and periphery of stacks. The incisions were thereafter closed with masking tape. In Multan two fumigations were carried out in August and December 1988, whereas in Lahore fumigation was conducted in September 1988 only and no additional fumigation was done as the stacks were found to be free of live insect infestation.

iv) Actual practice of the Food Handling Agency (P-4)

Actual practice of the Food handling agency was monitored in this protocol. The arrival and issue samplings were conducted as per procedures described earlier. In this protocol no treatment was applied by the laboratory staff and only monitoring of the procedures adopted by the Food Handling Agencies was done.

In all of the protocols at the time of stacking, nylon pipings were installed in the bottom, middle, and top central regions of the stacks. One tube was also placed in the free air space of the godown. All of the tubes were long enough to come out of the godown. These tubes were used for monitoring phosphine gas concentrations in different zones of each stack for which the Harris meter was used.

RESULTS AND DISCUSSIONS

Insect damaged grain and weight loss

In Multan at the time of storage the percentage of insect damaged grain was significantly higher ($p<0.05$) in PEPF (P-3) and control (P-4) (Table-I). At issue there was a significant increase in damage percentage in control (P-4) over rest of the protocols (p at the most 0.001). The difference in arrival and issue i.e. during storage period was highest in control (P-4) followed by the recommended practice (P-1), multiple dose fumigation (P-2), and PEPF (P-3) in that order. The difference between arrival and issue in the percentage damaged grain was significantly higher ($p<0.001$) in control (P-4) compared with all of the other protocols. However, no significant difference was recorded in multiple dose fumigation (P-2) and PEPF (P-3). The percentage increase of insect damaged grain during storage over arrival was highest in P-1 followed by P-4, P-2, and P-3 which indicates that the rate of insect damage was relatively slow in PEPF and multiple dose fumigation compared to the recommended practice (P-1) and control (P-4).

In Lahore at arrival the percentage of insect damaged grain was highest in control (P-4) followed by PEPF (P-3), and multiple dose fumigation (P-2) (Table-1). The arrival data of the recommended practice (P-1) could not be obtained. At issue the highest numbers of insect damaged grain were recorded in control (P-4) and multiple dose fumigation (P-2) followed by recommended practice (P-1), and PEPF (P-3). The difference in arrival and issue was maximum in P-2 succeeded by P-4, and P-3. There was an increase in percentage of insect damaged grains at dispatch over arrival of 3.65, 0.20, and 0.41 folds in P-2, P-4, and P-3, respectively (Table-1).

Table-1 shows that in Multan the total weight loss in agency controlled godown (P-4) was significantly higher than all of the other protocols ($p<0.001$). Interestingly, it was also found that the total weight loss in PEPF (P-3) was significantly higher ($p<0.05$) than multiple dose fumigation (P-2). However, this was due to the fact that percentages of insect damaged grain at arrival in PEPF (P-3) were substantially higher than that in multiple dose treatment (P-2). The actual storage loss in different treatments during storage was highest in control (P-4) followed by PEPF (P-3), multiple dose fumigation (P-2), and the recommended practice (P-1). The percentage increase in loss at issue over arrival was highest in P-4 followed by P-3, P-2, and P-1.

In Lahore weight loss was comparatively low due to better management including better hygienic conditions and relatively unfavourable environmental conditions for insect growth in all the treatments. A scrutiny of Table-1 reveals that the minimum weight loss and insect damage during treatment took place in protocol-3, whereas protocol-2 was most the effective treatment that registered a weight loss and insect damage of 0.44 and 0.62 %, respectively.

The composition of stored grain insect pest species plays an important role in determining the weevilization and subsequent weight loss as some of them are known to consume more grain during their life spans being "external feeders" whereas others are "internal feeders." Therefore, in cases where infestation is dominated by a complex of species a relationship between weight loss and

insect damage is difficult to establish as happened at Lahore. Species such as Trogoderma granarium and Tribolium castaneum are external feeders and are known to cause proportionate weight loss in an infested commodity. Weight loss in grain infested dominantly by such species can be related to their number as indicated by results of the Multan experiments.

Table 1 indicates that percentage increase (during storage) in the number of insect damaged grains in wheat stored at Multan for a period of one year was 0.93, 0.49, 0.40, and 3.67 for protocols-1, 2, 3, and 4, respectively. This shows the superiority of PEPF (P-3) over all other protocols. P-2 and P-1 followed P-3 in descending order while P-4 was the worst. At Lahore P-3 was also outstanding on this account as the percentage increase in insect damaged grain over a period of 13 months over storage of wheat under this protocol was only 0.113 percent which was the lowest of all. This position of P-3 at Lahore was despite the fact that wheat in this protocol was fumigated only once as against twice in protocols 1 and 2. The percentage increase in insect damage grain was 0.133 in nine months under P-4 as against 0.620 in 14 months under P-2. On the face of it, though P-4 appears superior than P-2 we know that insect population increases in geometric progression and that most species complete their life cycle in about four weeks. It can thus be estimated that if the wheat under P-4 would have remained under storage for 14 months as against present of nine months, the increase in number of insect damaged grain would have reached a level of about 1.6 folds i.e., double to the level of infestation in P-2. This shows that like Multan, P-3 was the best and P-4 was the worst at Lahore as well.

Changes in insect density during storage

The insect infestation was higher in Multan than in Lahore. In both the places eight species of stored grain insect pests were recorded that include Trogoderma granarium, Tribolium castaneum, Rhizopertha dominica, Sitophilus oryzae, Sitotroga cerealella, Corcyra cephalonica, Cryptolestis ferrugineus, and Oryzaephilus surinamensis. Of these, the first four were common while the rest occurred very rarely. Tables-2 and 3 show the relative density of the four insect pests at the time of arrival (storage) and at dispatch or termination of storage in the four protocols tested at Multan and Lahore respectively.

In Multan in Protocol-1, T. granarium and T. castaneum showed a 9.37 and 3.49 fold increase at dispatch compared to arrival. In Protocol-2, R. dominica and S. oryzae showed a greater increase, whereas in Protocol-3, T. castaneum and S. oryzae showed 23.16 and 88.12 fold increase, respectively, at dispatch compared to arrival. In Protocol-4, R. dominica and T. granarium exhibited 142.65 and 30.81 times increase, respectively, at dispatch over the arrival. The total insect density at dispatch was highest in P-4 followed by P-3, P-2, and P-1 in that order. In general, live insect density at dispatch was lower than that of dead insects. This was presumably due to natural mortality of insects as well as the mortality caused by insecticide. The reason why PEPF (P-3) was unable to check the insect density as effectively as agency controlled procedure is that the live insect density was higher at arrival in PEPF compared to other protocols.

The insect density in the four protocols of Lahore are shown in Table-3. Rhizopertha dominica was the predominant species followed by T. granarium, T.

castaneum, and S. oryzae in that order. The maximum infestation at the time of storage was recorded in P-1, followed by P-2, P-3, and P-4. At issue the insect density was highest in P-1 followed by P-4, P-2, and P-3. However, the increase in the number of total insects over arrival was found to be 1.05, 1.22, 1.10, and 1.63 folds for P-1, P-2, P-3, and P-4, respectively. This indicates that maximum increase in insect density took place in P-4. In P-1, R. dominica showed 1.0[illegible] fold increase at dispatch over arrival. In P-2, all three of the above referred predominant species showed an increase over arrival at dispatch to range between 1.17 to 1.49 folds. In P-3, increase was only recorded in the case of T. granarium (2.72 fold), whereas in agency control godown (P-4) the first three predominant species showed an increase ranging between 1.25 and 3.85 folds.

All the integrated pest management protocols failed to eliminate the four major insect pest species that infested the wheat in the experimental godowns both at Multan and Lahore. Live insects were always present at the termination of storage in all of the stacks though the species varied in various protocols (Tables-2 and 3). At Multan, live Rhizopertha dominica was eliminated as a result of treatment in P-1, P-3, and P-4 but not in P-2. Similarly T. granarium was eliminated from P-1 and P-2 but not in P-3 and P-4. Live T. castaneum and S. oryzae were present in all of the protocols at the time of termination of storage although S. oryzae was not even detected in any of the samples taken at the time of arrival (Table-2). At Lahore S. oryzae disappeared from all the dispatch samples under all protocols while T. granarium was eliminated from P-1 and P-3 but not from P-2 and P-4. Live R. dominica and T. castaneum were present in all the protocols at dispatch (Table-3).

Phosphine concentration over time

The first phosphine fumigations in Multan and Lahore were carried out in August and September 1988, respectively. Thereafter, in Multan, Protocols-1 and 3, the second fumigations were done in December 1988, and in Protocol-2 in February 1989. In Lahore, the second fumigations were carried out in May 1989 in Protocols-1 and 2, whereas Protocol 3 was not fumigated as it was found free of infestation. The concentrations of phosphine after fumigation in different protocols in Multan and Lahore are shown in Figures 1a to 1f. It is generally recommended that in order to achieve an adequate control of insect populations, a minimum phosphine concentration of 200 ppm should be maintained for at least five days. In cases where resistant populations exist, the exposure period should be at least seven to eight days to achieve a reasonable control.

In Multan, during first fumigation in Protocol-1 the phosphine concentration of 200 ppm was maintained for only two and one half days which clearly implies that the fumigation was inadequate. Due to high insect attack, the second fumigation in the same protocol was carried out in December 1988. A higher dosage than one tablet per cubic meter was used, and this time the lethal concentration was maintained for six days (Figure 1a). In multiple dose fumigation (P-2) carried out in August 1988, an initial dose of 1.5 tablets per cubic meter was applied which was followed by a second dose of one tablet per cubic meter applied on the third day of the initial dosing. A peak concentration of 680 ppm was achieved within 24 hours after treatment. Second dose resulted in another peak of 490 ppm and in this way the lethal concentration was maintained for about five days. The second single dose phosphine fumigation was carried out in the same protocol

(P-2) during February 1989, the lethal concentration for more than six days was maintained at the dosage rate of about one tablet per cubic meter (Figure 1b). Due to higher retention of gas, the multiple dosing was not considered cost economic in this protocol. In PEPF (P-3), the first fumigation was carried out in August, 1988. A lethal concentration of 200 ppm or more was maintained for six days. Due to increased insect activity, the second fumigation was carried out in February, 1989 with the same dose and that retained the lethal phosphine concentration for more than 10 days (Figure 1c).

In Lahore the first fumigations in all of the protocols were carried out in September 1988. The gas persisted in these godowns for a longer duration than in Multan. In Protocol-1 the lethal phosphine concentration was retained for four and one half days (Figure 1d). In Protocol-2 the lethal concentration was maintained for seven days (Figure 1e), whereas in PEPF (P-3) the lethal concentration was retained for 11 days (Figure 1f). The second fumigation in Lahore was carried out only in Protocols-1 and 2 during May 1989, whereas Protocol-3 was not fumigated as it did not develop any insect infestation.

It was evident in all the protocols that none of the fumigation methods could control or totally eliminate the insects from the commodity in almost all the fumigations. The reasons for insect survival are basically high leakage rates of godowns and presence of highly resistant strains of stored grain insect pests. It is therefore felt that if any success in fumigation is desired, the only way is to adopt PEPF (P-3) with some modifications as it certainly has edges over other treatment procedures. In this technique, the exposure period can be increased at a lower concentration which is considered as a prerequisite for successful fumigation (Bell 1986).

Cost and effectiveness of the protocols

The effect of inputs and the value of grain lost to insects in Multan and Lahore is given in Table-4. In Multan the quantity and value of loss was highest in the agency controlled godown (P-4), followed by PEPF (P-3), multiple dose fumigation (P-2), and the recommended practice (P-1) in that order. The cost of treatment (total expenditure) was highest for multiple dose fumigation (P-2), followed by PEPF (P-3), recommended practice (P-1) and agency controlled (P-4). The second fumigation was carried out in Protocols-1, 2 and 3 due to the increased insect activity. The cost of treatment in P-1 includes the cost of malathion (for surface spraying) and two fumigations with 3229 and 3664 AlP tablets in August and December 1988, respectively. The cost of treatment in P-2 includes the cost of Actellic and the cost of two fumigations with 8074 and 3665 AlP tablets in August 1988 and February 1989, respectively. The treatment cost for P-3 included two fumigations with 1512 and 1728 AlP tablets in August and December 1988, and the depreciated cost of 260 Kg of polyethylene. The cost given for P-4 is estimated and is comprised of a single fumigation in October 1988. Thus in Multan the net cost (total expenditure + value of loss) was highest for the agency control (P-4) followed by multiple dose fumigation (P-2), PEPF (P-3), and the recommended practice (P-1). On the basis of net cost per tonne per month the recommended practice (P-1) showed the lowest cost of Rs0.96 followed by PEPF (P-3) of Rs1.44, multiple dose fumigation (P-2) of Rs 1.60, and the agency controlled (P-1) of Rs 3.99.

In Lahore the cost of treatment in P-1 includes two surface sprays and two single dose fumigations (3024 tablets per fumigation) carried out in September 1988 and May 1989. In P-2, surface spray, peripheral spraying of bags and multiple dose fumigation (each with 7560 tablets) were carried out twice, one in September 1988 and the other in May 1989. In P-3 the cost of treatment includes the depreciated cost of 240 kg polyethylene (polyethylene can be resold at one third of initial cost) and the cost of one fumigation carried out in September 1988 by using 1336 AlP tablets. The cost given for P-4 is estimated and includes the cost of one fumigation and the cost of Actellic for surface and bag spraying. In Lahore, the weight loss data for P-1 at arrival could not be recorded and the calculations are therefore based on the assumptions that at the time of arrival no weight loss or insect damage had occurred in this protocol. Table-4 shows that in Lahore the net cost was highest in P-2 followed by P-1, P-4, and P-3. The net cost therefore is lowest for PEPF though its expenditure was higher than P-4. The net cost per tonne per month for P-3 was calculated as Rs 1.51 as compared to Rs 2.11 in P-2, Rs 0.99 in P-1, and Rs 0.89 in P-4.

It is evident from the study that in Lahore P-3 was the most cost effective method of storage. The perusal of Multan data also reveals similar results though a confusing picture emerges due to the reason that grain at the time of arrival in P-3 was heavily infested as compared to P-1 which apparently gives an impression of P-1's superiority over P-3. But if we consider insect damaged grain as another criterion for measuring the weight loss, that shall show that the increase (during storage) in number of insect damaged grain at Multan was 0.93, 0.49, 0.40, and 3.67 folds for Protocols-1, 2, 3, and 4, respectively. This clearly shows the superiority of P-3 over rest of the protocols. At Lahore also P-3 was outstanding on the account that the increase in insect damaged grain over a period of 13 months of storage in this protocol was only 0.113 fold which was the lowest of all. This position of P-3 at Lahore was despite the fact that the wheat under this protocol was fumigated only once as against two times in P-1 and P-2. P-1 in Lahore cannot be compared because of non-availability of arrival data. P-2 and P-4 are also not directly comparable because storage under P-4 was terminated after nine months as against 14 months under P-2. The percentage increase in insect damaged grain was 0.133 in nine months under P-4 as against 0.620 in 14 months under P-2. On the face of it, P-4 would appear to be superior to P-2 which, however, is not true, because the insect population increases in geometric progression and that most species complete their life cycle in about four weeks under environmental conditions that existed in Lahore. It can thus be estimated that if the wheat under P-4 had remained under storage for fourteen months the increase in number of the "insect damaged grains" would have reached a level of about 1.6 folds. This shows that like Multan, P-3 was the best and P-4 the worst of all protocols at Lahore as well.

TABLE 1

GRAIN DAMAGE AND LOSS PRODUCED BY INSECTS DURING STORAGE IN BAGS AT MULTAN & LAHORE, PAKISTAN UNDER FOUR PEST MANAGEMENT PROTOCOLS

Treatments	Percent insect damaged grain			X-fold increase over arrival	Weight loss percentage			X-fold increase in loss over arrival
	Pre-treatment (Arrival)	Total (Dispatch)	Storage (Difference)		Pre-treatment (Arrival)	Total (Dispatch)	Actual storage loss (difference)	
Multan								
Recommended practice (P1)	0.23 0.18	1.16 0.95	0.93	4.04	0.16 0.11	0.29 0.36	0.13	0.81
Multiple dose fumigation (P2)	0.26 0.28	0.75 0.89	0.49	1.88	0.19 0.20	0.38 0.35	0.19	0.99
PEPF (P3)	0.75 0.35	1.15 1.13	0.40	0.53	0.31 0.38	0.65 0.37	0.34	1.10
Agency Controlled (P4)	0.92 0.73	5.20 1.53	3.67	3.99	0.37 0.31	2.03 0.72	1.66	4.49
Lahore								
Recommended Practice (P1)		0.520 0.094				0.310 0.054		
Multiple Dose fumigation (P2)	0.170 0.150	0.790 0.604	0.620	3.647	0.280 0.362	0.720 0.457	0.440	1.571
PEPF (P3)	0.277 0.211	0.390 0.096	0.113	0.408	0.178 0.111	0.190 0.071	0.012	0.067
Agency Controlled (P4)	0.657 0.341	0.790 0.214	0.133	0.202	0.271 0.127	0.444 0.095	0.173	0.638

*Data not recorded

TABLE 2

DENSITY OF FOUR MAJOR INSECT PESTS (#/kg) AND THE TOTAL DENSITY AT ARRIVAL AND DISPATCH IN THE FOUR PROTOCOLS AT MULTAN

Treatment	Insect Species	Live A	Live D	X-fold increase (+) or decrease (-)	Dead A	Dead D	X-fold increase (+) or decrease (-)	Total A	Total D	X-fold increase (+) or decrease (-)
Protocol 1	R.d	3.04	0.00	$$	0.50	0.00	$$	3.54	0.00	$$
	T.g	0.48	0.00	$$	0.79	11.90	+15.06	1.27	11.90	+9.37
	T.c	0.73	3.86	+5.29	0.74	1.27	+1.72	1.47	5.13	+3.49
	S.o	0.00	0.32	$	0.00	0.00	0.00	0.00	0.32	$
	Tot	4.25	4.18	-1.02	2.03	13.17	+6.49	6.28	17.35	+2.77
Protocol 2	R.d	0.73	2.01	+2.75	0.27	5.13	+19.00	1.00	7.14	+7.14
	T.g	0.54	0.00	$$	0.12	3.05	+25.42	0.66	3.05	+4.62
	T.c	0.38	9.78	+25.74	1.62	0.69	-2.35	2.00	10.47	+5.23
	S.o	0.00	1.12	$	0.15	0.00	$$	0.15	1.12	+7.47
	Tot	1.64	19.91	+7.87	2.16	8.88	+4.11	3.80	21.79	+5.73
Protocol 3	R.d	0.32	0.00	$$	0.73	0.52	-1.40	1.06	0.52	-2.04
	T.g	16.05	2.50	-6.42	1.85	12.28	+6.64	17.90	14.78	-1.21
	T.c	0.09	160.34	+1780.33	6.98	3.54	-1.97	7.07	163.77	+23.16
	S.o	0.00	4.45	$	0.08	2.60	+32.50	0.08	7.05	+88.12
	Tot	16.46	167.18	+10.16	9.64	18.93	+1.96	26.10	186.11	+7.13
Protocol 4	R.d	1.50	0.00	$$	1.55	435.08	+280.69	3.05	435.08	+142.65
	T.g	2.35	3.04	+1.29	3.96	191.40	+48.33	6.31	194.44	+30.81
	T.c	0.62	0.33	-1.88	105.01	0.69	-153.09	105.63	1.01	-104.58
	S.o	0.00	0.80	$	1.07	0.00	$$	1.07	0.80	-1.34
	Tot	4.47	4.17	-1.07	111.59	627.16	+5.62	116.05	631.33	+5.44

A = Arrival, D = Dispatch, R.d = Rhizopertha dominica, T.g = Trigoderma granarium, R.c = Tribolium castaneum, S.o = Sitophilus oryzae, Tot = Total insects, $$ Places where insect density has decreased to zero level, $ = Places where insect density has increased over zero level

TABLE 3

DENSITY OF FOUR MAJOR INSECT PESTS (#/kg) AND THE TOTAL DENSITY AT ARRIVAL AND ISSUE IN THE FOUR PROTOCOLS AT LAHORE

Treatment	Insect Species	Live A	Live D	X-fold increase (+) or decrease (-)	Dead A	Dead D	X-fold increase (+) or decrease (-)	Total A	Total D	X-fold increase (+) or decrease (-)
Protocol 1	R.d	54.20	5.67	-9.56	17.57	13.45	-1.31	71.28	76.48	+1.06
	T.g	0.88	0.00	$$	0.86	0.37	-2.32	1.24	0.37	-3.35
	T.c	4.59	0.38	-12.08	2.74	3.93	+1.43	7.35	4.32	-1.70
	S.o	0.91	0.00	$$	0.42	0.23	-1.83	1.33	0.23	-5.78
	Tot	60.58	6.05	-10.01	21.59	17.98	-1.20	77.70	81.40	+1.05
Protocol 2	R.d	14.73	23.21	+1.61	12.18	8.52	-1.43	26.72	31.72	+1.19
	T.g	0.31	0.12	-2.58	1.01	1.42	+1.40	1.32	1.54	+1.17
	T.c	1.15	4.75	+4.13	3.41	2.06	-1.65	4.56	6.80	+1.49
	S.o	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	$$
	Tot	15.83	28.08	+1.77	16.60	12.00	-1.38	32.72	40.07	+1.22
Protocol 3	R.d	7.20	8.86	+1.23	6.71	6.67	-1.00	21.05	15.54	-1.35
	T.g	1.35	0.00	$$	4.42	15.58	+3.52	5.77	15.72	+2.72
	T.c	0.00	0.20	$	7.80	7.07	-1.10	7.80	6.93	-1.12
	S.o	0.00	0.00	0.00	0.11	0.00	$$	0.11	0.00	$$
	Tot	8.55	9.06	+1.06	19.04	29.32	+1.54	34.73	38.19	+1.10
Protocol 4	R.d	9.97	0.69	-14.45	4.70	17.71	+3.77	14.69	18.41	+1.25
	T.g	2.40	0.13	-18.46	12.03	29.48	+2.45	14.44	26.87	+1.86
	T.c	0.00	0.46	$	1.17	4.09	+3.49	1.17	4.50	+3.85
	S.o	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00
	Tot	12.37	1.28	-9.66	18.15	51.28	+2.82	30.55	49.78	+1.63

A = Arrival, D = Dispatch, R.d = Rhizopertha dominica, T.g = Trigoderma granarium, R.c = Tribolium castaneus, S.o = Sitophilus oryzae, Tot = Total insects, $$ Places where insect density has decreased to zero level, $ = Places where insect density has increased over zero level

TABLE 4

COST OF PEST CONTROL INPUTS AND THE VALUE OF GRAIN LOST UNDER THE FOUR STORAGE PROTOCOLS FOR BAGGED GRAIN IN MULTAN CODOWNS

Parameters	Multan (Protocols)				Lahore (Protocols)			
	P1	P2	P3	P4	P1	P2	P3	P4
Quantity stored (tons)	1000	100	1000	500	1000	1000	1000	1000
Storage period (months)	12	12	12	12	15	14	13	9
Weight loss %	0.13	0.19	0.34	1.66	0.31*	0.440	0.012	0.173
Quantity lost (tons)	1.3	1.90	3.40	8.30	3.10	4.40	0.12	1.73
Value of loss (Rs)	3120.00	4560	8160.00	19920.00	7440.00	10560.00	288.00	4152.00
Total expenditure (Rs)	8397.00	14599.00	9089.00	4000.00	7383.00	18927.00	6403.00	3873.00
Net cost (Rs)	11517.00	19159.00	17249.00	12920.00	14828.00	29487.00	6691.00	8025.00
Net cost/ton/year (Rs)	11.52	19.16	17.25	47.84	11.86	25.27	6.18	10.7
Net cost/ton/month (Rs)	0.96	1.60	1.44	3.99	0.99	2.11	0.91	0.89

*Figure based on the assumption that the grain at the time of arrival in protocol-1 was free of insect damage.

ACKNOWLEDGEMENTS

The authors are grateful to Dr's. Hafiz Ahmed, Ex-Director, PARC, Karachi, Richard C. Maxon, U. A. Acasio, J. Pederson, and C. Reed of FFGI, Kansas State University for their continued interest in this study and provision of facilities. Thanks are also due to staff of PASSCO and Punjab Food Department for their valuable help and arrangement of facilities. This project was supported by USAID through their STDT, FSM Project Contract No. 391-0491-C-00-60-80-00. Their support is greatly acknowledged.

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A SURVEY OF RESISTANCE TO PHOSPHINE AND CONTACT INSECTICIDES IN MAJOR PESTS OF STORED WHEAT AND RICE IN PAKISTAN

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ABSTRACT

Forty strains of R. dominica, 43 of T. castaneum, eight of T. granarium and four of S. oryzae collected from various parts of Pakistan were tested for their resistance to phosphine. Fifty five and 46.5% of the tested strains of R. dominica and T.castaneum exhibited various degrees of resistance, whereas all the strains of S. oryzae and T. granarium were found to be resistant. The resistant factors in R. dominica range between two and 85, in T. castaneum two and 162, in T. granarium 11 and 36, and in S. oryzae one and 27. For monitoring the level of resistance in R. dominica, T. castaneum, and S. oryzae against malathion 16, 14, and eight strains respectively were tested. None of the strains were found to be susceptible. The RF values in these species range between eight and 240, four and 350 and eight and 31 in that order. Sixteen strains of stored grain pests were tested against fenitrothion; all of them were found to be resistant. The maximum RF value recorded was that of 138 for R. dominica. Out of 34 strains of stored grain pests tested against Actellic, seven were found to be susceptible whereas others exhibited the RF value ranging between two and 91.

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INTRODUCTION

Stored grains disinfestation by phosphine fumigation and use of contact insecticides on godown fabric are the major means of preventing damage by insect pests during storage. The sub-standard techniques of fumigation in the leaky structures where lethal concentrations of phosphine are not maintained for sufficient durations have led to the development of resistance in major insect pests of stored products (Mills 1983, Taylor 1989). The problem is not circumvented by increasing the dosage because such application is not only uneconomical but high dosages may cause narcosis which permits increased survival of insects (Nakakita et al. 1974). Similarly application of sub-lethal dosages of contact insecticides by unskilled workers may lead to a situation where the insecticides may become totally ineffective in controlling the stored grain pests (Irshad and Gillani 1990).

The resistance problem with storage pests was first highlighted internationally at the FAO symposium on resistance of agricultural pests to pesticides held in Rome in September 1960. The severity of the problem can be seen from the fact that resistance in stored grain insects has developed rapidly from three species in 1960 to eight and 14 species in 1964 and 1970, respectively. By now, resistance against phosphine and almost all the commonly used insecticides has been reported to have developed in all the major stored grain insect pests. Champ and Dyte (1976) reported after a global survey that 82 out of 849 strains of stored grain insect pests of different species had developed some level of resistance against phosphine. Borah and Chahal (1979) reported the failure of phosphine to control the khapra beetle, Trogoderma granarium in warehouses in India. Tyler et al. (1983) documented the resistance in stored grain insect pests to phosphine in Bangladesh. The major tolerant species was R. dominica though other species including T. castaneum, O. surinamensis, and Cryptolestis spp. also exhibited a reduced degree of susceptibility to phosphine. Taylor (1989) recorded three out of four strains of R. dominica and seven out of eight strains of Tribolium casteneum to have developed resistance against phosphine in Pakistan. Alam and Ahmed (1989) reported that the resistant factor against phosphine in Pakistan ranges between 0-162 and 0-85 folds in different strains of T. castaneum and R.dominica respectively. Accounts of the laboratory assessment of the insect pests from various tropical countries have also been given by Attia and Greening (1981), Mills (1983), and Taylor (1986). It is, therefore, apparent that if the situation regarding use of phosphine is not adequately tackled, phosphine would eventually become a non-toxic gas to major insect pests of stored grain. The severity of the problem is intense, as presently there is no alternate fumigant to phosphine available anywhere in the world.

MATERIAL AND METHODS

Insect material adults or larvae of Rhizopertha dominica, Tribolium castaneum, Sitophilus oryzae, and Trogoderma granarium were collected from 1977 to 1990 from government warehouses located in various cities of Pakistan. The godowns were known to be infested with insects and had a history of annual phosphine fumigation and contact insecticide application for at least three years. At the time of insect collection the relevant data concerning insect infestation was recorded. That also included details of warehouse, location, and a report of the insecticides that have been used for insect control, etc. Such information was gathered on a proforma. The collected insects were brought to the laboratory and reared on appropriate medias for multiplication at controlled temperature and humidity. The strains of various species were initially subjected to discriminating dose tests for phosphine and contact insecticides as recommended by FAO (Anonymous 1975 and Anonymous 1974, respectively). The strains found to be resistant at discriminating doses were further tested at increased dosages to record their "resistant factor." In all of the tests a control of susceptible strains was maintained and treated in a similar manner. The susceptible strains of R. dominica, T.castaneum, and S.oryzae for "control" were provided by ODNRI(UK) and CSIRO Australia, whereas T. granarium, the strain collected from Karachi with lowest LD50 (0.917 mg/l), was taken as "reference strain". All of the tests were triplicated for obtaining accuracy. Due consideration was given to the principles and recognitions as recorded by Anonymous (1969) and Anonymous (1970).

For phosphine generation, AlP tablets were used and phosphine was collected over acidified water, desiccators (10.81 litre vol.) served as fumigation chambers. Within the desiccator, insects were confined in 50 cc beakers closed with nylon mesh. Aliquots of phosphine gas were injected into the desiccators with micro syringes through a rubber septum fitted to a socket in the desiccator lid. The treated batches along with the susceptible strains were placed in an environmental chamber at 25° C and 65% relative humidity up to the recommended durations. Dosage mortality data was analyzed by computer, based on the method of Finney 1971. The resistant factor was calculated by using the following formula:

$$\text{Resistance factor} = \frac{\text{LD 50 of resistant strain}}{\text{LD 50 of susceptible strain}}$$

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RESULTS

a) Resistance to phosphine

A total of 95 strains of R. dominica, T. castaneum, T. granarium, and S.oryzae were collected from different localities of Pakistan for evaluating their levels of resistance against phosphine. Out of this, 40 strains were of R.dominica, 43 of T. castaneum, eight of T. granarium, and four of S. oryzae. A total of 22 strains of R.dominica were found susceptible (55%) (one from Lahore, five from Multan, three from Sargodha, four from Peshawar, five from Mansehra and four from Durgai). In the case of T. castaneum, 20 strains were found susceptible (46.5%) (one from Karachi, two each from Multan, Peshawar and Mansehra; three each from Lahore, Faisalabad and Durgai; and four from Nankana Sahib). All the strains of T. granarium and S. oryzae were found resistant except one of T. granarium collected from Karachi that has been taken as a reference for comparison. The results of the strains found resistant to phosphine are being depicted in Figures 1, 2, 3, and 4. A scrutiny of Figure 1 will reveal that the highest level of phosphine resistance in Rhizopertha dominica was found in the strains collected from Karachi, Sargodha and Hyderabad during 1989, 1987, and 1988, respectively (RF ranging between 80 and 85). The strain collected from Mansehra in 1987 exhibited the resistance factor of 74 folds which is the next highest. The Lahore and Peshawar strains showed relatively less levels of phosphine resistance. Figure 2 shows the level of phosphine resistance in nine susceptible strains of Tribolium castaneum. The highest level of resistance in this species was found in strains collected in 1989 from Karachi (RF = 162) followed by the strain collected from Mansehra that exhibited a resistance factor of 80 folds. Out of 23 resistant strains of this species, three exhibited RF values greater than 50, and 17 greater than 10 folds. It is quite obvious from the figures that the mean level of phosphine resistance in T. castaneum has increased progressively in Karachi from 1987 to 1989, whereas for other cities sufficient data is not available to draw any conclusion. Figure 3 shows the occurrence of phosphine resistance in Trogoderma granarium in Multan, Karachi, and Muzaffargarh. Altogether seven strains of T. granarium were compared with the reference strain collected from Karachi. The maximum level of resistance (36 folds) was found in the strain collected from Muzaffargarh in 1990. All the strains tested exhibited a resistance factor higher than 10 folds. Figure 4 shows the occurrence of phosphine resistance in Sitophilus oryzae. Altogether four strains of this species were collected from Karachi and analyzed for determining the level of phosphine resistance. The strains collected during 1990 showed the maximum RF value of 27 folds.

b) Resistance to malathion

Thirty eight strains of stored grain insect pests collected from Karachi were tested for monitoring their level of resistance against malathion. Out of these, 16 strains were of R. dominica; 14 of T. castaneum and eight of S. oryzae. None of the strains exhibited any susceptibility and all of them were found to be resistant. The results are shown in Figure 5. The maximum level of resistance recorded in R. dominica was that of 240 RF value followed by 150. The resistance factor seems to have increased progressively from 1987 to 1989. In T. castaneum the maximum level of resistance factor registered was that of 350 in the strain collected in 1987 followed by 303 in the strain collected in 1988. Out of the

14 strains tested, eight had an RF value higher than 50 whereas 12 had RF values higher than 20. In all, eight strains of S. oryzae were analyzed for their RF values which were found to be higher than 25 in four strains and higher than 10 in six strains.

c) Resistance to fenitrothion

Sixteen strains of stored grain insect pests were collected from Karachi for evaluating their level of resistance against fenitrothion. Five of these were of R. dominica, seven of T. castaneum, and four of S. oryzae. The results are depicted in Figure 6. None of the strains tested were found to be susceptible to fenitrothion. The maximum level of resistance in R. dominica was recorded in the strain collected in 1989 (RF = 67). In T. castaneum, the maximum resistance factor recorded was that of 138, whereas six out of seven strains had RF values greater than 20. In S. oryzae four strains were tested. The maximum RF value recorded was that of 68 followed by 66.

d) Resistance to Actellic

Thirty four strains of stored grain insect pests were tested for monitoring their level of resistance against Actellic. Fourteen of the strains were of T. castaneum, 12 of R. dominica and eight of S. oryzae. Out of these, five strains of T. castaneum and one each of R. dominica and S. oryzae were found to be susceptible. The maximum level of resistance in T. castaneum recorded was that of 91 folds. Out of nine resistant strains of this species, six exhibited RF values greater than 20. In R. dominica the maximum RF value of 53 was recorded in the strain collected in 1988. Five strains exhibited the RF values greater than 20 folds. Eight strains of S. oryzae were tested, one that was collected from Lahore exhibited an RF value of 78, whereas the results of six resistant strains collected from Karachi are shown in Figure 7. The maximum resistant factor of 24 was recorded in the strain collected in 1988. Five strains out of six had a resistant factor greater than 20.

DISCUSSION

A wide variation in the response to phosphine among different strains of adult Tribolium castaneum & Rhizopertha dominica and full grown larvae of Trogoderma granarium has been demonstrated in this study. Borah and Chahal (1979), and Mills (1983) have shown good correlation between laboratory assessment of phosphine resistance and the results of fumigation in the field. Furthermore, demonstration of phosphine resistance in adult insects clearly implies that there is resistance in other stages of insects. Bell et al. (1977) showed that resistance level in adults of R. dominica correspond with resistance in egg stage, while in T. castaneum greater resistance to phosphine has been observed more in early- and mid-pupal stages than in adults (Nakakita and Winks, 1980). Thus, demonstration of phosphine resistance in adult insects clearly implies that there could be problems in controlling both adults and immature stages of insect pests in commodities infested by resistant strains. Failure of phosphine fumigation attributable to resistance in T.granarium and R. dominica has been recorded from Multan and Karachi. The warehouses in these places have a history of 12 years of phosphine fumigation. Though sufficient information is not available, such situations may be prevalent in some other localities. The primary cause of the development of resistance is the use of sub-standard fumigation techniques that includes leakiness of warehouses that leads to sub-optimal doses. Gas leaks not only from mud plastered doors and ventilators but also through the porous walls. This problem can be largely circumvented by enclosing grain stacks in polyethylene sheets (Tyler et al. 1983, Ahed et al. 1986,and Ahmed and Shaukat 1990). Tyler et al. (1983) and Taylor (1989) have suggested an increase in exposure period to assure complete insect mortality. Since the fumigation under gas-proof polyethylene sheet permits the retention of gas for a longer period, this technique should be preferred to the usual practice of total warehouse fumigation. To ensure standard fumigation, the operators must be adequately trained. Where the phosphine resistance has developed to very high levels methyl bromide can be considered as an alternative means to control insects (Tyler et al. 1983).

The results of phosphine resistance shows that the most effected species is T. castaneum followed by R. dominica, that registered more RF values comparing to S oryzae and T. granarium. The localities where a history of long phosphine application prevailed were comparatively more effected. There was no apparent relationship in the level of phosphine resistance in the strains tested from the same locality in different years and it is difficult to establish with the current data whether the phosphine resistance in Pakistan is increasing or decreasing with time. The considerable variations in the levels of phosphine resistance is apparent, particularly in T. castaneum and R. dominica strains collected from different localities. The RF values of T. castaneum collected from Karachi ranged between two and 165, whereas these values in R. dominica ranged from two in Durgai to 80 in Hyderabad, Karachi, and Sargodha. The discriminating concentration for T. granarium is not yet established hence the minimum LD50 value recorded from a Karachi strain was taken as a reference and other strains were compared with the reference strain. All of the strains of this species exhibited an RF value above 10.

In the case of contact insecticides the maximum resistance seems to have

developed in T. castaneum against malathion collected from Karachi (RF=350). Most of the strains of this species along with R. dominica exhibited RF values above 50 which clearly indicate the high level of resistance that has developed against Malathion. The possible reason for developing such a high level of resistance against this insecticide could be its wide spread & improper use by unskilled persons for several years. The ineffectiveness of malathion particularly against T. castaneum has also been reported by Irshad and Gillani (1990). They tested 40 strains of T. castaneum against malathion and have recorded RF values of three to 244.3 at farm level; 51.4 to 201.0 at flour mills and 6.6 to 232.6 at public-sector stores and concluded that T. castaneum cannot be controlled by malathion in Pakistan. The other organophosphate "Actellic" also appeared to be partially effective against T. castaneum, R. dominica, and S. oryzae, though its use in the public sector in Pakistan is mainly in RECP and PASSCO warehouses. A similar situation also exists for fenitrothion, which has developed far more resistance despite of its limited application. This is presumably due to the structural similarities in the three organophosphorus compounds that lead to development of cross resistance in stored grain insect pests despite their limited use.

It is, therefore, required that use of malathion in public-sector warehouses should be banned, whereas other contact insecticides should be handled by trained manpower so that they may not also become totally ineffective against stored grain insect pests. At the same time, the new insecticides should also be screened for their possible use in foodgrain warehouses.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Hafiz Ahmed, Ex-Director, PARC, Karachi and Dr. R.C. Maxon of FFGI (USA) for their continued interest in the study and provision of necessary facilities. M/s. D. Halliday, R.W.D. Taylor, and A. Harris of ODNRI (UK) deserve very special thanks for initiating this study. The equipment was jointly supplied by ODA and USAID. Their support is greatly acknowledged.

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FUMIGABILITY OF GODOWNS IN PAKISTAN

by

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ACKNOWLEDGMENTS

The authors wish to gratefully acknowledge the assistance of all those at the Natural Resources Institute, and in Pakistan who participated in the study. Mention should particularly be made of staff of the Grain Storage Laboratory (GSRL) of PARC in Karachi and Lahore, the Rice Export Corporation of Pakistan (RECP), the Pakistan Agricultural Storage and Services Company (PASSCO), the Provincial Food Departments, and the Kansas State University Food Security Management Project based in Lahore. The authors are particularly grateful for the encouragement and help provided by Dr. A. Hafeez and A. Mubarek of GSRL, Dr. R. Maxon of KSU, Colonel Taj of PASSCO, and the operational staff of RECP based at Bin Qasim.

FUMIGABILITY OF GODOWNS IN PAKISTAN

Background and Pattern of Work

It is common practice in Pakistan to try to control insect infestation of food grains by fumigating the whole godown in which they are stored with phosphine. This is accomplished after sealing gaps around doors, windows, and any other obvious likely sources of leakage of gas, with mud plaster. This is followed by application of solid formulations of aluminum phosphide which releases phosphine as it reacts with atmospheric moisture. This approach to pest control is used particularly by the Provincial Food Departments and PASSCO, many of the staff of which have now received some training in grain storage technology under the auspices of a programme funded by the World Bank. This programme led to contact between the Grain Storage Research Laboratory (GSRL) of PARC based in Karachi and the Natural Resources Institute (NRI), which in turn led to the development of a collaborative programme of research and training in fumigation technology. This programme, which was funded by ODA under the auspices of an agreed programme of assistance to PARC, was conducted in 1987 at Karachi, Lahore, and Rawalpindi.

The programme at Karachi was centred on enabling GSRL to investigate possible development of resistance to phosphine by the more important pests of stored grains in Pakistan. This emphasis reflected a concern that the fumigation of grains in structures which were incompletely gas-tight over a period of many years, might have led to the development of resistant strains of insects. Concurrently with this, trial fumigations were carried out at the Bin Qasim complex of RECP to assess the fumigability of the godown and "Binishells" in use for holding stocks of rice awaiting processing. The godowns had been built in the early 1970's, while the binishells dated from the early 1980's. The trials included a preliminary investigation of possible methods of improving concentration time patterns for phosphine by varying the type of formulation and method of application. This work took place in February/March when conditions were cool and dry.

A second phase of investigations was conducted in October/November 1987 in which the fumigability of godowns used for wheat storage by PASSCO at Manga Mindi near Lahore and by the Punjab Food Department in Rawalpindi was investigated. The godowns at Manga Mindi had been built to a design developed by PASSCO, later versions of which were erected in many other locations throughout Pakistan under the auspices of the previously mentioned World Bank project. Some of the godowns at Manga Mindi were atypical of the later standardized design in that they had pre-cast concrete roofs and double rather than single hinged doors. The structures at Rawalpindi were also brick-walled house-type godowns, which had been built in the 1950's to a design and specification repeated in other towns throughout Pakistan at that time.

The outcome of the 1987 programme coupled with earlier observations by GSRL raised considerable interest in the possibility of making a comprehensive structural survey of the types of godowns used for grain storage in Pakistan and an assessment of their suitability for fumigation with phosphine. It was hoped that the results of the survey might be used to develop guidelines for a more organized approach to pest control, which might be followed routinely by PASSCO and the four Provincial Food Departments of Sind, Punjab, North-West Frontier and

Baluchistan. The survey and accompanying fumigation trials were carried out in October - December 1989 and July/August 1990 and entailed further fieldwork in Karachi, Lahore, Manga Mindi, Peshawar/Aza Khel, Rawalpindi, Islamabad, Bahawalpur, Multan, and Quetta. The report of the structural survey is given in Appendix 1, while the fumigation trials are reported in Appendices 2 to 8 (see Table 1).

Results of Structural Survey

It will be seen from Appendix 1 that following main types of godowns were identified:

House-Type: these were mostly built during the 1950's. They have 500 mm thick load-bearing brick walls and flat roofs and have a nominal capacity of 1000 tonnes of bagged grain.

PASSCO: these were built from the mid-1970's onwards. During this period there has been a gradual improvement in quality of construction and certain design features. They have 500 mm thick brick walls and flat roofs and have a nominal capacity of 1100 tonnes of bagged grain.

Stepped Roof: these were built mostly in the early 1970's. The structures are framed with non-loadbearing 250mm thick walls of hollow concrete blocks or brick. Capacity varies up 16000 tonnes of bagged grain.

National Logistics Corporation (NLC): these were built in 1979. They consist of blocks of units each having a nominal capacity of 5000 tonnes of bagged grain. The structures are framed with 250mm thick non-loadbearing walls. Roofs are barrel vaulted with valley gutters.

Binishells: these are reinforced spherical shell domes of 150mm thickness. Nominal capacity is 1500 tonnes of bagged grain.

Hexagonal Bins: these are bulk silos built of brick in multiple units, each with 37 tonnes capacity. Thickness of walls is 400mm. They were built around 1945.

Cells: these were only seen at Quetta and had been built in 1945. They had been formed by dividing up a building into units of 50 tonnes grain storage capacity.

RECP Godowns at Bin Qasim: these date from the early 1970's and are of framed construction mostly with walls constructed from concrete blocks and concrete slab roofs coated with bitumen. They are in rows, each unit being of some 1800 tonnes nominal capacity for the storage of milled rice in bags.

Other Types: several other types of godowns observed in particular locations are described in Appendix 1. These include one similar to the stepped roof and one of corrugated iron.

The godowns were systematically surveyed for dimensions, capacity, volume, and the construction and state of floors, walls, roofs, doors, ventilators, roof/wall joints, and wall/floor joints. On the basis of this data, the potential of the structure to hold phosphine gas was assessed using a scoring system. By this means it was possible to conclude that House-Type (1), PASSCO (2), NLC (4), and Hexagonal Bins (6) all had the potential to retain phosphine gas for periods which should prove sufficient to control any insect infestation. However, this was dependant on their being well-maintained and properly sealed. The other types of structures were all likely to be unsuitable for fumigation although there were possible ways in which phosphine retention might be improved, e.g. painting walls with a paint impermeable to gases.

Fumigation Trials

While structural examination greatly assists in the prediction of the likely fumigability of grain stores, their performance in this respect must be confirmed by the monitoring of phosphine concentrations during the course of a fumigation. This not only provides confirmation on the inherent ability of the structure to retain fumigant gas, but also enables possible variations in this to be correlated with ambient optimal dosages, form, and patterns of application of solid phosphine formulations under different ambient conditions. The present programme was designed to provide such information and to use it to develop practical guidelines for controlling insect infestation of grains stored in the different types of godowns.

It will be seen from Table 1 that fumigation trials were carried out on a total of seven sites over a period of some three and a half years. The trial were undertaken in six of the types of godowns identified during the course of the structural survey. Other types were omitted due to their obvious unsuitability for fumigation and/or other evidence which had been generated from other sources, e.g. the programmes of GSRL, as to their fumigability. It was recognized that ambient temperature and relative humidity were important factors in determining the likely outcome of fumigations, through their influence on the ate of evolution of phosphine and efficacy against the insect pests. For operational reasons, the timing of these was mostly during the period October - November when ambient conditions tend to be cool and dry, but some were carried out during February/March and July/August when conditions are warmer and/or more humid. Full reports of the individual trials are given in Appendices 2 to 9 as follows:

2. Fumigation of Rice Godowns at the RECP Bin Qasim Complex with Phosphine, February/March 1987

3. Fumigation of Binishells at the RECP Bin Qasim complex with Phosphine, February/March 1987

4. Report on Preliminary Experiments to Determine the Fumigability of PASSCO Godowns at Manga Mindi, October/November 1987

5. Experiments to Develop Improved Procedure for Fumigation of PASSCO Godowns Containing Wheat Stored as "Bag and Bulk" at Manga Mindi, August 1990

6. Report on Experiments to Determine Fumigability of House-Type Godowns at Rawalpindi, November 1987

7. Fumigation of House-Type Godowns in Peshawar and NLC Godowns at Aza Khel, November 1989 and August 1990

8. Fumigation of House-Type Godown at Multan, November 1989

9. Fumigation of Grain Storage Cells in Quetta, November 1989

Experiments at Bin Qasim (Appendices 2 and 3). These were the first carried out by NRI in Pakistan and focused on assessing the fumigability of the godowns and binishells used by RECP for the storage of milled rice awaiting processing to a standard appropriate for export. In assessing fumigability, the possibilities of using formulations such as sachets which release phosphine more slowly than tablets and multiple dosing so as to extend the period for which lethal concentrations of gas are maintained, were also explored. The conclusions reached were as follows:

> Godowns: it is not possible to achieve satisfactory fumigations in this type of godown except by the use of sachet formulations which release phosphine more slowly than tablets. These sachets have to be applied in two equal doses of 0.5g phosphine per cubic metre separated by a period of 48 hours, i.e. a total dose of 1.0g per cubic metre, if satisfactory concentration time patterns are to be achieved. In this way, it was possible to maintain phosphine concentrations of 0.3mg per litre for periods of three days and of 0.2mg per litre for five days. These conditions are marginally adequate to give a satisfactory fumigation.
>
> Binishells: these were found to be unsuitable for fumigation even when using sachet formulations and multiple dosing.

These findings are in accord with the conclusions of the structural survey (Appendix 1).

Experiments at Manga Mindi, Lahore (Appendices 4 and 5). Experimental fumigations were carried out in PASSCO godowns, some of which were of an early superseded version with pre-cast concrete roofs and which were inferior in construction to the standard type of PASSCO godown now widely distributed throughout Pakistan. The first set of experiments in October 1987 quickly established that, when adequately maintained, the standard PASSCO godown was fumigable using conventional methods of applying phosphine as solid table formulations. For example, it was demonstrated that one standard PASSCO godown loaded with wheat and fumigated with a single dose of 1.56g phosphine per cubic metre, maintained a concentration of 0.3mg phosphine per litre or more in the free space for a period of between five and six days. The earlier types of godowns retained phosphine less well, but there was evidence to suggest that patterns of phosphine concentration over time could be substantially improved by the use of multiple dosing.

In order to increase storage capacity, PASSCO has adopted the practice of loading its godowns with bulk wheat retained with bag walls, This "bag and bulk" system

has enabled 1400 tonnes or more to be contained within each godown rather than the rated capacity of 1100 tonnes of wheat in bags. It quickly became apparent during the course of the first experiments that phosphine was only penetrating slowly form the free space into the bulk of wheat. With the current practice of applying fumigant only to the periphery, there was considerable danger of parts of the bulk receiving sub-lethal doses of phosphine. The two later experimental programmes at Manga Mindi were, therefore, aimed at developing a technique of applying phosphine which would overcome this problem. It has been demonstrated that partial application of phosphine through four vertical slotted plastic pipes inserted at positions along the centre of the bulk was likely to enable lethal concentrations of phosphine to be maintained over a period of time adequate to control any infestation. After further refinement, it is hoped that this technique of application will be brought into general use by PASSCO.

Experiments at Rawalpindi, Peshawar and Multan (Appendices 6, 7, and 8). These were carried out in the house-type godowns constructed in the 1950's fully loaded with bags of wheat. Such godowns are used extensively by Provincial Food Departments and have provided excellent service with minimal maintenance over many years. Experimental fumigations at the above three sites indicated that this type of godown retained phosphine very well despite an often rather dilapidated appearance. This is a tribute to their original high standard of construction and a renovation programme currently in operation should effect further improvements in gas retention. Periods for which concentrations were maintained at 0/3mg phosphine per litre or above in the experimental godowns are given in Table 2.

It will be seen from Table 2 that when a single dose of around 1.24mg phosphine was applied to the free space, house-type godowns were able to maintain a concentration of 0.4 mg phosphine per litre for around three days, 0.3mg per litre for between three and one half and four days and 0.2mg per litre for five days or more. It is interesting to note that the one fumigation carried out under monsoon conditions yielded concentration patterns which were substantially better than the others. This suggests that the more humid conditions at that time, which would be expected to accelerate evolution of phosphine, are beneficial. However, this needs to be confirmed with further experiments. It will be seen from Table 3 of Appendix 6 that multiple dosing appeared to have little beneficial effect on concentration time patterns.

Experiments at Aza Khel (Appendix 7). These were carried out in godowns of 5000 tonnes capacity erected by the National Logistics Corporation (NLC) in 1979. Two fumigations were carried out in godowns which were about half-filled with bags of wheat. Rates of application of phosphine and concentration achieved over time are summarized in Table 3. It will be seen that the NLC godowns retained phosphine very well despite their large capacity and light loading.

Experiments at Quetta (Appendix 9). These were carried out in storage "cells" constructed in 1945, each of which is able to accommodate around 80 tonnes of wheat. This type of structure was found to retain phosphine very poorly and it was difficult even to achieve concentrations of 0.2mg phosphine per litre. Quite clearly these structures must be classified as unfumigable, as indicated also in Appendix 1 on the basis of the structural survey.

CONCLUSIONS AND RECOMMENDATIONS

It is possible to classify the grain storage structures into three types with respect to fumigability.

1. Those godowns which when in a good state of repair, are fully fumigable using a single initial dose of phosphine. This should be applied to the free space when all the grain is in bags. When grain is stored as "bag and bulk", approximately one half of the total dose should be applied to the bulk of grain through slotted plastic tubes as described in Appendix 5. The standard brick house-type godowns of the 1950's, the hexagonal bins circa 1945, the PASSCO godowns of the 1970's and 1980's, and the NLC godowns of the late 1970's, which all fall within this category, constitute the major resource of godowns for grain storage in Pakistan.

2. Those godowns which are at best only marginally suitable for fumigation due to limitations in their structural design. However, good maintenance coupled with the use of multiple dosing techniques may enable satisfactory fumigations to be performed. This category includes the RECP godowns at Landhi and Bin Qasim constructed in the 1970's.

3. Those godowns which by virtue of their design and construction are completely unfumigable. These include the stepped roof godowns of the 1970's, the "cells" at Quetta and all binishells.

Studies of the efficacy of phosphine against strains of common beetle pests of stored grains in Pakistan by GSRL and NRI have indicated variable degrees of resistance to phosphine at major storage sites. This is presumably the legacy of a long history of poorly-performed fumigations extending over many years and has to be taken into account when recommending dosages which might be routinely recommended. Unfortunately, the amount of data available on resistance to phosphine is insufficient to make other than very generalized recommendations on rates of application of phosphine which might be used. If it is assumed that a successful fumigation is likely when a concentration of 0.3mg phosphine per litre or more is maintained for between four and five days and 0.2mg per litre for six or more days, and application rate of 1.5mg phosphine would seem to be suitable for the fully fumigable structures (Class 1 above), but sachet formulations which release phosphine more slowly are more appropriate for godowns which are only marginally suitable for fumigation (Class 2 above). There seems to be no evidence to support any need to vary dosage to accommodate seasonal variations in temperature and relative humidity.

Any grain in non-fumigable structures (Class 3 above) must be fumigated under gas-proof sheets, taking proper precautions to endure that adequate sealing is obtained. A dosage rate of 1g phosphine per cubic metre coupled with a fumigation period of seven days should be adequate to ensure a good outcome under all conditions.

In deciding on recommended rates of application of phosphine it has been necessary to make an arbitrary assumption with regard to efficacy against the most serious insect pests of stored grains in Pakistan. It had been hoped that

GSRL would have developed more information on this subject since 1987, but because of operational problems outside its control, this has not proven possible. It is strongly recommended that GSRL continue its programme of testing strains of Rhyzopertha dominica, Tribolium castaneum, and other beetle pests for resistance to phosphine and use the data from this to refine recommendations for rates of application of phosphine and fumigation periods.

The possible wider use of bulk handling and storage systems for wheat will introduce additional problems of pest control by virtue of difficulties in sealing the flat bulkheads and silos used for this. Perhaps the most appropriate approach to pest control in these systems is application of contact insecticides as sprays at the time loading as is practiced in Australia and Europe.

TABLE 1

Godown Fumigability Trials Carried Out Under Supervision of NRI Staff 1987 - 1990

Location	Date	Appendix No.	Godown Type
RECP, Bin Qasim	Feb/March 1987	2	(8)
" " "	" " "	3	(5)
Manga Mindi, Lahore	Oct/Nov 1987	4	(2)
" " "	October 1989	-	(2)
" " "	August 1990	5	(2)
Rawalpindi	November 1987	6	(1)
Peshawar (Kohat Rd)	November 1989	7	(1)
" " "	August 1990	7	(1)
Aza Khel (Nowshera)	November 1989	7	(4)
Multan	November 1989	8	(1)
Quetta	November 1989	9	(7)

Types of Godowns (See Appendix 1 for Structural Details)

(1) House-type godowns with brick walls built in 1950's with 1000 tonne capacity.
(2) PASSCO godowns with 1100 tonnes capacity.
(4) National Logistics Corporation godowns with 5000 tonnes capacity built in 1979.
(5) Binishells with 1500 tonnes capacity.
(7) Cells with 50 tonnes capacity built in 1945.
(8) RECP godowns with 1800 tonnes capacity built in early 1970's.

TABLE 2
Concentration of Phosphine Achieved Over Time in House-Type Godowns

Location of godown and Date of Experiment		Dose Applied g Phosphine cubic m	No. of Hours 0.2, 0.3 and 0.4 mg Phosphine per 1 Maintained		
			0.2mg/1	0.3mg/1	0.4mg/1
Rawalpindi	November 1987	1.24	130	94	72
"	"	1.24	146	132	102
"	"	1.24	184	163	132
Peshawar	November 1987	1.23	110	87	66
"	"	1.23	125	96	140
"	August	1.00	165	164	65
Multan	November 1989	1.11	136	105	74

PHOSPHINE FUMIGATION OF BULK WHEAT IN PAKISTAN

by

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INTRODUCTION

Bulk wheat is being stored by food handling agencies in the following different types of storage facilities:

i - House-type godowns

ii - Hexagonal bins

iii - Open Bulkheads

iv - Vertical Silos

In the house-type godowns, bag cum bulk storage is presently being practiced by PASSCO and the conversion of these godowns for complete bulk wheat storage is under trial. The present total volume of bag cum bulk storage by PASSCO is 450,000 mt.

Hexagonal bins or hex bins are being used by provincial food departments (PFDs) for bulk wheat storage. These bins were constructed in the late 1940's and early 1950's. Each bin can hold about 36 tonnes of wheat and the total storing capacity is about 303,000 mt in-country.

Open bulkheads are newly built facilities for storage of bulk wheat. The technology was imported from Australia in 1986. About 30 open bulkheads have so far been erected in Pakistan with a combined wheat storage capacity of 150,000 mt. At first, portable inclined bucket elevators were employed for filling wheat in bulkheads. But due to very low conveying capacity and other draw-backs, their use was abandoned. Later on, manual labour was utilized each year for loading and unloading of these facilities. Now, due to the induction, under the STDT project, of a new type of portable equipment with higher conveying capacity, these bulkheads are again being loaded mechanically.

Vertical silos are also being used to store bulk wheat at Khairpur, Multan, and Chichawatni by the Punjab Food Department and PASSCO. More silos are under construction at Faisalabad and Karachi. Silos have been constructed at Quetta as well, but these are not presently being used. The combined vertical silo storage for wheat in the country is about 302,000 mt.

Phosphine Fumigation of Bulk Wheat

Research work carried out by the Grain Storage Research Laboratory (GSRL) of the Pakistan Agricultural Research Council (PARC) and under the Storage Technology Development and Transfer (STDT) project has shown that our godown buildings are generally leaky and therefore unsuited for proper phosphine fumigation (Alam et al., 1984 and Ahmed et al., 1991). This is the major cause of the development of resistance to phosphine in stored grain pests (Halliday et al., 1983 and Friendship et al., 1986). Furthermore, studies both by the STDT project and GSRL have revealed that Pakistani wheat contains a high amount of dust (Ahmed et al., 1988) which could create problems in phosphine fumigation of bulk wheat. The STDT project therefore decided to undertake detailed studies in this field in

collaboration with GSRL. A lot of research work was carried out in this connection, the details of which are presented here.

Fumigation of Bag-Cum-Bulk Wheat in House-Type Godowns

Bag-cum-bulk storage of wheat is being undertaken by PASSCO in house-type godowns to increase its capacity from 1,100 mt to 1,600 mt/godown. In this practice, bulk wheat is contained in an area enclosed by pad walls made of wheat bags. Each enclosure is 28.78 m in length, 17.10 m in width, and 3.64 m in height. The present practices of pest management include: i) surface spraying of empty godown's interior with Actellic, and ii) whole-godown phosphine fumigation by using Aluminum Phosphide (AlP) tablets at the dosage rate of one standard sized tab/cu m (M^3) of space.

To evaluate the current phosphine fumigation procedure and to improve its effectiveness, the following three procedures were tried in 1989-90.

i - Fumigation using a single dose of Aluminum Phosphide tablets

ii - Fumigation by multiple dose of Aluminum Phosphide tablets

iii - Fumigation by using dosing pipes

i. Fumigation by Single Dose of Aluminum Phosphide

In this case, the same fumigation procedure was adopted as is being used by PASSCO except that fumigation was carried out by the researchers themselves. Before fumigation, the godown's interior was sprayed with the recommended dose of Actellic. The internal volume of the godown was measured to apply Aluminum Phosphide (AlP) tablets at the rate of 1 tab/M^3. The total number of tablets were scattered around and on the surface of the bag-cum-bulk. The doors and ventilators were closed and mud plastered to make the godown airtight. Phosphine gas was monitored from outside of the godown through nylon tubes coming out from different positions inside the godown and the wheat bulk with help of a 'Cititox' phosphine meter (Harris and Cox, 1990).

Results presented in Table 1 and Figure I are from the experiment in godown No. 14 of the PASSCO complex (Manga) and showed that a very high concentration of phosphine gas was attained in the free space after 24 hours of dose application. The gas penetrated into the grain mass but could not reach the bottom portion of bulk wheat in sufficient quantity during this period. The required minimum concentration of more than 200 ppm could be retained only for about 5 1/2 days in almost all parts of the grain. In the bottom central zone of the wheat bulk, gas penetration was slow and was retained there for a comparatively longer period (Figure I). This retention pattern of phosphine gas, however, varied considerably from godown to godown depending upon the state of leakiness. It was found that another godown (No. 4) at the same complex was not fumigable at all (Figure II) because it could not retain the essential minimal level of gas concentration at any of the monitoring positions in the grain bulk or the free space, although the dose used in both the godowns was the same.

ii. Multiple dose application of AlP tablets

In this method, a higher dose rate of AlP tablets/M^3 of space was applied in two parts. The first dose was applied at the rate of 1.5 tab/M^3 while the second dose of 1.0 tab/M^3 was applied after 48 hours. The results showed (Table 1) that the minimum essential concentration of more than 200 ppm of phosphine gas could be retained for nine days in the free space as against only five days in the bottom central zone of the wheat bulk (Figure III). In the top peripheral and middle semi-peripheral zones, gas could retained for nine and six days, respectively (Table 3 and Figure III). As such, despite the higher dose rate of 2.5 tab/M^3, the essential minimum concentration of phosphine gas could not be maintained in all parts of the bulk for a sufficiently long period which was essential for complete success of fumigation.

iii. Phosphine fumigation by using dosing pipes

It was noted in the above experiments that the penetration of phosphine gas in deeper parts of the grain mass was comparatively slow and as a consequence, the essential minimum concentration of gas in these zones could only be retained for five to six days which was not adequate to kill all insects present in these areas. Such incomplete fumigations not only require repeated fumigations adding to the costs, but also lead to the development of resistance to phosphine in insects. Furthermore, very high concentration of phosphine gas in free space leaks out of the godown, perhaps due to thermal expansion of the gasses in the free space. To overcome these difficulties, it was decided to try to deliver the AlP tablets at various depths and at various places within the wheat bulk instead of placing the tablets on the outside of the bulk.

In this method, therefore, PVC pipes were fixed with the central pillars of the godown so that they remained about 1/2 m above floor level. Each dosing pipe was 13 cm in diameter and 4 m in height, having rings of perforations. Each ring was separated by a 50 cm blank portion. Three-fourths portion of each pipe was immersed in the bulk grain. The dose rate of AlP tablets remained the same, i.e one tab/M^3. A total of 3,200 tablets per godown were used. Out of these total tablets, 960 tablets were mixed with grain and poured in four dosing pipes in equal number in such a way that two bands of such mixture separated by normal grains were formed. The remaining 2,240 tablets were scattered around and on the surface of grain bulk as is the usual practice. Doors and ventilators of the godown were made airtight by applying mud plaster. Concentration of phosphine was recorded from various zones in the grain bulk.

Results presented in Table 1 and Figure IV showed that more than 200 ppm of phosphine gas was present in the free space, top peripheral, and middle semi-peripheral zones of the wheat bulk for seven days and for more than nine days in the bottom central zone (Table 4 and Figure IV). The overall exposure period thus attained improved a little but was still not adequate for those insects which had acquired a high degree of resistance to phosphine. In the light of these observations, it can be concluded that gas-tightness of the godowns will have to be improved for proper phosphine fumigation of wheat in house-type godowns where bag-cum-bulk is being practiced.

Phosphine Fumigation in Hexagonal Bins

Hexagonal bins or hex bins have been used by the PFDs since the 1940's to store wheat in bulk. Phosphine fumigation is the main tool used to protect the wheat from insect damage in these bins. Presently, fumigation is being carried out by placing the AlP tablets on the grain surface. To monitor the present fumigation practice and to devise some improvements, a study was conducted last year (1990). A total of 12 bins loaded with 432 tonnes of wheat were used in these fumigation experiments. Most of the bins were filled mechanically with the help of a grain pump. The bottom spouts and upper manholes were sealed by applying mud plaster after the application of fumigant. For monitoring of phosphine gas, nylon pipes were installed before fumigation at three depths in the grain mass and one above the grain surface in the free space. The three depths were 0.75, 3.00, and 5.50 m from the top grain surface and they were named as top, middle, and bottom, respectively. The following three different methods of fumigation were tested.

i - Single dose application of AlP tablets

ii - Multiple dose application of AlP tablets

iii - Improved method for application of AlP tablets

i. Single Dose Application of AlP Tablets

In this method, phosphine fumigation procedure as laid down by the Punjab Food Department was followed in three bins. The dosage rate was 2 tab/tonne and all the tablets were placed on the grain surface in each bin.

It was observed that very high concentration of phosphine gas was achieved in free space after 24 hours and critical requirement i.e 200 ppm remained there for only six days (Table-2). In the top and middle layers, this critical concentration was attained only for five and three days, respectively. In the bottom zone, this concentration could not be attained even for a short time (Table 5 and Figure V).

In light of these results, it was concluded that the present fumigation practice is not adequate. The insect data obtained during this study indicated that the live insects were present in all parts of the bins although their intensity decreased from top to bottom. The insects present in the deeper zones, in spite of their small numbers, received sub-lethal doses of phosphine. Such situations lead to increased resistance in the surviving insects against phosphine.

ii. Multiple dose application of AlP tablets

In this method, a higher dosage rate of AlP tablets per bin and two successive application of tablets were used. For the first dose, 108 tab/bin (dose rate 2.5 tab/tonne) were placed on the grain surface and after 48 hours, the bin was opened briefly and another dose of 72 tablets (@ 2 tab/ton) was dropped in as quickly as possible.

The results (Table 2 and Figure VI) showed no significant difference as compared

to the single dose application method, particularly in respect to fumigation of the bottom parts of the bins. There was some increase in the concentration of phosphine in the top and middle grain layers (Table 2 and Figure VI) but the difference was not proportionate to the increase (2.50 folds) in the number of tablets applied. There was also no change in the gas retention period.

iii. Improved Method of Application of AlP Tablets

From the above studies, an important fact of significance emerged that the critical level of 200 ppm of gas concentration was not achieved for a sufficient period in any part of the bin, especially in the bottom zone. It was therefore decided, to try another method in which AlP tablets were buried in the grain mass instead of placing them on the top. The normal dose of 72 tablets per bin was divided into two equal portions. One portion was deposited at a depth of about 5 m, while the other was buried about 1 m deep in the grain mass (Figure VII). The tablets were deposited at the required depths with the help of a special tablet applicator (Figure VIII). The bins were then sealed in the usual way.

It was observed (Table 2 and Figure IX) that the critical amount of phosphine gas in top, middle, and bottom zones was retained for 12 days, whereas it was retained for nine days in free space (Table 2 and Figure IX). The gas retention and distribution pattern achieved in this method of application was considered satisfactory. So, successful fumigation can be achieved by following this method. The retention period can further be extended by the application of another dose in a similar pattern after seven or eight days to take care of resistant strains as well as immature stages of all species.

Fumigation of Open Bulkheads

Open bulkheads are very important horizontal storage facilities in our country. Important constraints other than the conveying systems, in their use are (a) lack of any reliable and cheap covers, and (b) absence of a tested method of grain protection from insect infestation. These constraints have made the use of these facilities rather limited. The first constraint was removed by importation of fiber reinforced covers, while for removal of the second constraint, studies were initiated last year (1990). Four open bulkheads located at Depalpur and Okara were used for these trials. Of these, three bulkheads were covered with imported plastic sheets while the fourth was covered with ordinary tarpaulin and served as a control for comparison. The dosage rate used for fumigation was two AlP tab/tonne of wheat. Total number of tablets were distributed to cover the entire bulkhead by inserting the tablets half way down the grain mass at equal distance from each other with help of an AlP tablet applicator. At each insertion point, 20-30 tablets were deposited to provide even distribution of fumigant in the grain mass. The bulkhead was then covered with plastic sheets while the control was covered with tarpaulin. On the top, the sheet overlapping was held together under the weight of sand filled bags while its loose ends on the ground were held under the weight of loose earth all around the bulkhead. Other possible leakage points were also closed using PVC tape. Phosphine gas concentration in different zones was monitored through nylon tubes using a 'Cititox' phosphine meter.

In the control bulkhead, over 200 ppm gas concentration was retained for eight days in the middle zone near the point where AlP tablets were inserted (Figure

X). Top grain layers could retain gas only for five days, which may be due to upward movement of the gas leading to its ultimate leakage through the tarpaulin cover. Lethal concentration could not therefore, be attained in all parts of the bulkhead for even a short period (Table 3 and Figure XI).

In the other three bulkheads, phosphine gas was retained for more than nine days in all parts of the grain mass (Tables 4, 5, 6 and Figures XII, XIII, XIV). The gas distribution and retention pattern seemed to be satisfactory for successful fumigation. The exposure period can further be extended by using a low density polyethylene sheet on the inner surface of retaining steel wall and on the top of the bulkhead combined with the multiple dose technique for the application of AlP tablets.

Fumigation of Silos

Silos are other important bulk storage facilities owned by the Punjab Food Department and PASSCO. Presently, the operational sites are located at Multan, Chichawatni, and Khairpur. In all of these silos, automatic AlP pellet dispensers have been provided for phosphine fumigation but these are seldom used because of two major constraints: i) the pallets are not generally marketed in Pakistan, and ii) the silo can not be filled all at one time. It takes many days, sometimes weeks, before a silo is completely filled. Under these circumstances, for fumigation, AlP tablets are placed at the grain top as is being done in hex bins. This method has already been shown to be defective (Table 2 and Figure 5). This year plans are being prepared to develop methodology for improving fumigation of silos. In the first phase, insect distribution pattern in silos will be studied. The presence of insects will be observed in different depths of silos by taking out grain samples from various depths with help of a new grain sampler.

In the second phase, a suitable system of fumigation will be developed for silos.

ACKNOWLEDGEMENTS

The authors are highly grateful to Dr. Hafiz Ahmed, Consultant, STDT project; Dr. R. C. Maxon, Chief of Party, STDT project; and Dr. U. A. Acasio, Long-Term Advisor, STDT project, for their valuable suggestions and continued interest throughout this study. This work was financially supported by the STDT/FSM project. Their support is greatly acknowledged.

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TABLE 1

Results of Phosphine Fumigation in Bag Cum Bulk Storage in the House-Type Godown

METHOD	Days after initial dosing	Concentration (ppm) of phosphine gas at different points			
		Free space	Top Peripheral	Middle Semi-peripheral	Bottom Central
SINGLE DOSE	1	1000	850	580	60
	2	800	810	780	275
	3	480	570	540	400
	4	350	410	400	380
	5	230	250	240	310
	6	180	200	195	235
	7	100	100	110	135
	8	80	80	90	90
MULTIPLE DOSE	1	500	270	20	0
	2	590	460	40	0
	3	820	630	110	90
	4	890	730	350	130
	5	630	610	380	200
	6	490	530	400	260
	7	400	470	340	200
	8	230	310	320	280
	9	190	250	260	210
DOSING PIPES	1	263	253	201	>2000
	2	408	406	332	>2000
	3	443	452	448	>2000
	4	414	420	425	>2000
	5	379	391	389	1476
	6	316	322	329	1068
	7	249	248	255	789
	8	203	206	209	560
	9	177	175	178	431

TABLE 2
Concentration of Phosphine Gas in the Air Monitored at Four Points in Wheat Loaded Hex Bins

METHOD	Days after initial dosing	Average Conc. (ppm) of phosphine gas at four points			
		Free Space	Grain top	Grain middle	Grain bottom
SINGLE DOSE	1	3362	690	142	Nil
	2	1338	838	370	80
	3	752	510	330	78
	4	470	365	207	58
	5	327	227	183	40
	6	213	160	125	37
	7	128	83	60	30
MULTIPLE DOSE	1	3720	1072	193	15
	2	2022	1120	507	63
	3	3032	1112	463	55
	4	1290	830	468	65
	5	562	458	305	35
	6	290	270	200	20
	7	133	113	90	30
	8	85	100	60	20
IMPROVED METHOD	1	245	865	380	320
	2	405	995	575	445
	3	430	990	620	505
	4	390	750	615	525
	5	360	700	615	495
	6	335	615	580	470
	7	285	540	485	410
	8	260	400	440	360
	9	220	370	380	320
	10	190	305	340	295
	11	155	255	280	245
	12	130	200	235	200
	13	110	165	185	165
	14	90	135	150	120

TABLE 3

Concentration of Phosphine Gas in Bulk Wheat Loaded Open Bulkhead (control, i.e. covered with tarpaulin) at Depalpur

Days after initial dosing	Average Conc. (ppm) of phosphine gas in wheat bulk				
	BP*	TP*	MS*	BC*	TC*
1	9	27	1031	108	355
2	10	89	1058	123	349
3	19	90	971	81	243
4	11	56	802	57	209
5	18	25	672	44	215
6	7	63	545	40	187
7	11	24	429	9	151
8	9	45	265	23	102
9	8	29	163	12	65

*BP - Bottom peripheral
TP - Top peripheral
MS - Middle semi-peripheral
BC - Bottom central
TC - Top central

TABLE 4

Concentration of Phosphine Gas in Bulk Wheat Loaded Open Bulkhead at Depalpur (No. 1)

Days after initial dosing	Average Conc. (ppm) of phosphine gas in wheat bulk				
	BP*	TP*	MS*	BC*	TC*
1	187	475	342	43	190
2	437	590	522	92	793
3	546	706	668	215	782
4	549	672	649	400	769
5	572	728	700	490	800
6	595	739	716	556	826
7	676	781	729	627	709
8	490	694	667	595	704
9	418	578	563	578	565

*BP - Bottom peripheral
TP - Top peripheral
MS - Middle semi-peripheral
BC - Bottom central
TC - Top central

TABLE 5

Concentration of Phosphine Gas in Bulk Wheat Loaded Open Bulkhead at Depalpur (No. 2)

Days after initial dosing	Average Conc. (ppm) of phosphine gas in wheat bulk				
	BP*	TP*	MS*	BC*	TC*
1	741	798	>2000	249	220
2	952	1690	>2000	563	471
3	1010	1514	1743	753	602
4	981	1244	1410	762	730
5	770	1023	1048	720	705
6	680	845	834	648	644
7	594	711	732	553	561
8	515	605	620	450	455
9	425	508	513	342	335
10	370	427	455	317	300
11	309	324	347	293	280

*BP - Bottom peripheral
TP - Top peripheral
MS - Middle semi-peripheral
BC - Bottom central
TC - Top central

TABLE 6

Concentration of Phosphine Gas in Bulk
Wheat Loaded Open Bulkhead at Okara

Days after initial dosing	Average Conc. (ppm) of phosphine gas in wheat bulk				
	BP*	TP*	MS*	BC*	TC*
1	676	936	216	313	438
2	1103	1464	570	472	860
3	1247	1522	764	683	1022
4	1163	1365	743	814	981
5	1140	1256	786	861	1002
6	1082	910	746	716	844
7	458	575	256	466	406
8	380	505	245	405	390
9	298	426	160	342	305

*BP - Bottom peripheral
TP - Top peripheral
MS - Middle semi-peripheral
BC - Bottom central
TC - Top central

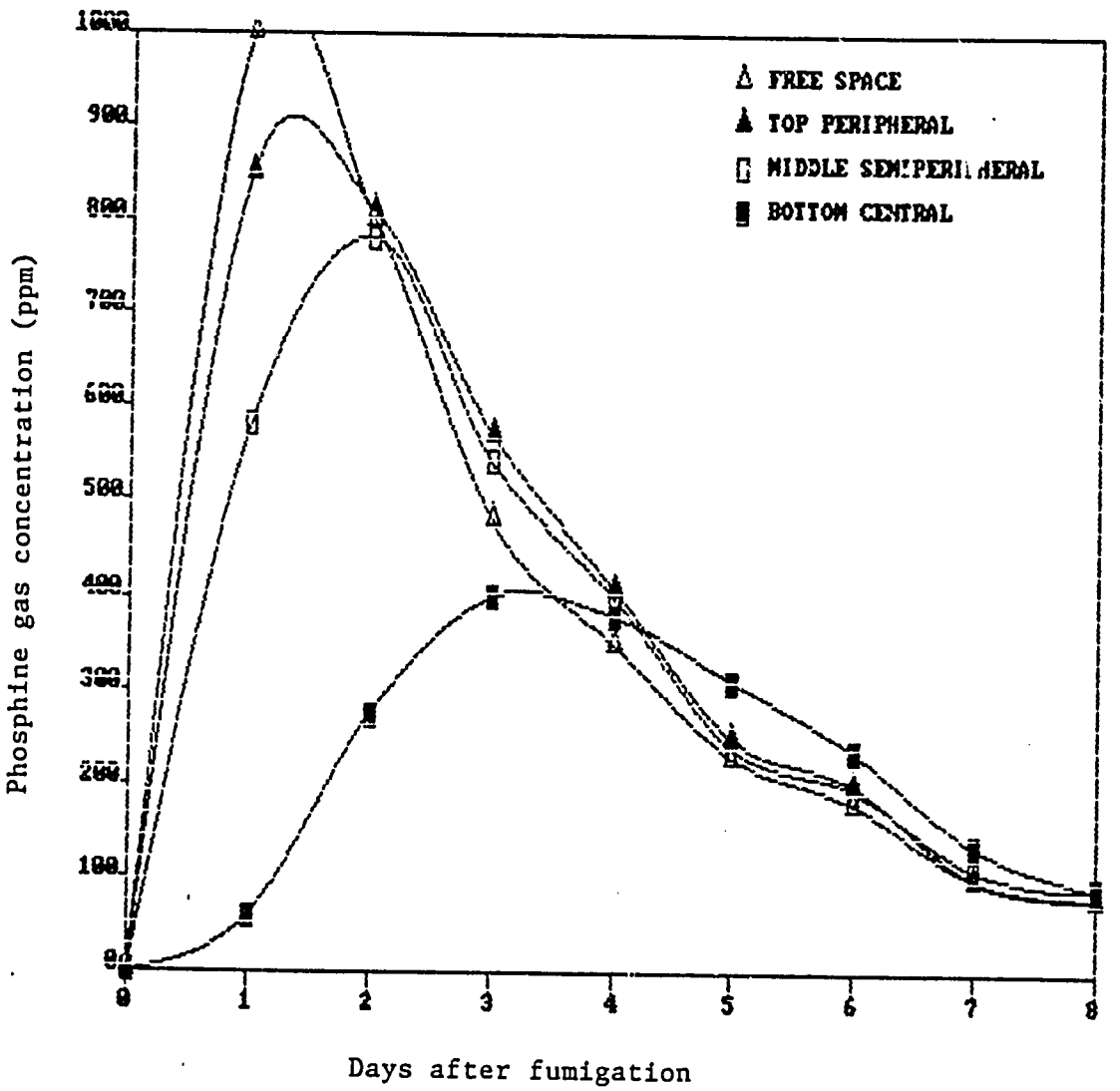

Fig. I: Phosphine gas concentration at various positions by using single dose AlP tablets in house-type godown No. 14.

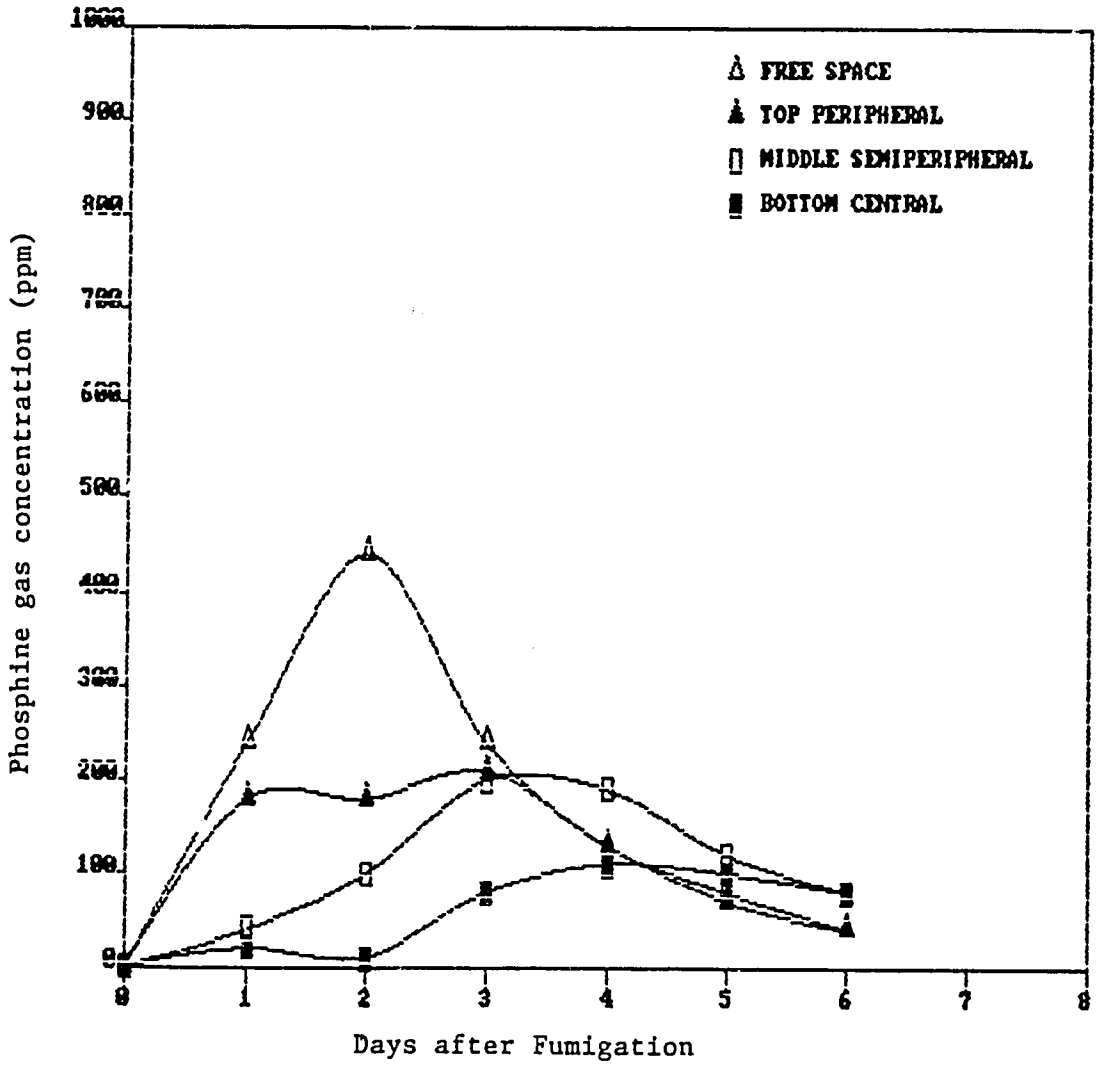

Fig. II. Phosphine gas concentration at various positions by using single dose of AlP tablets in house-type godown No. 4.

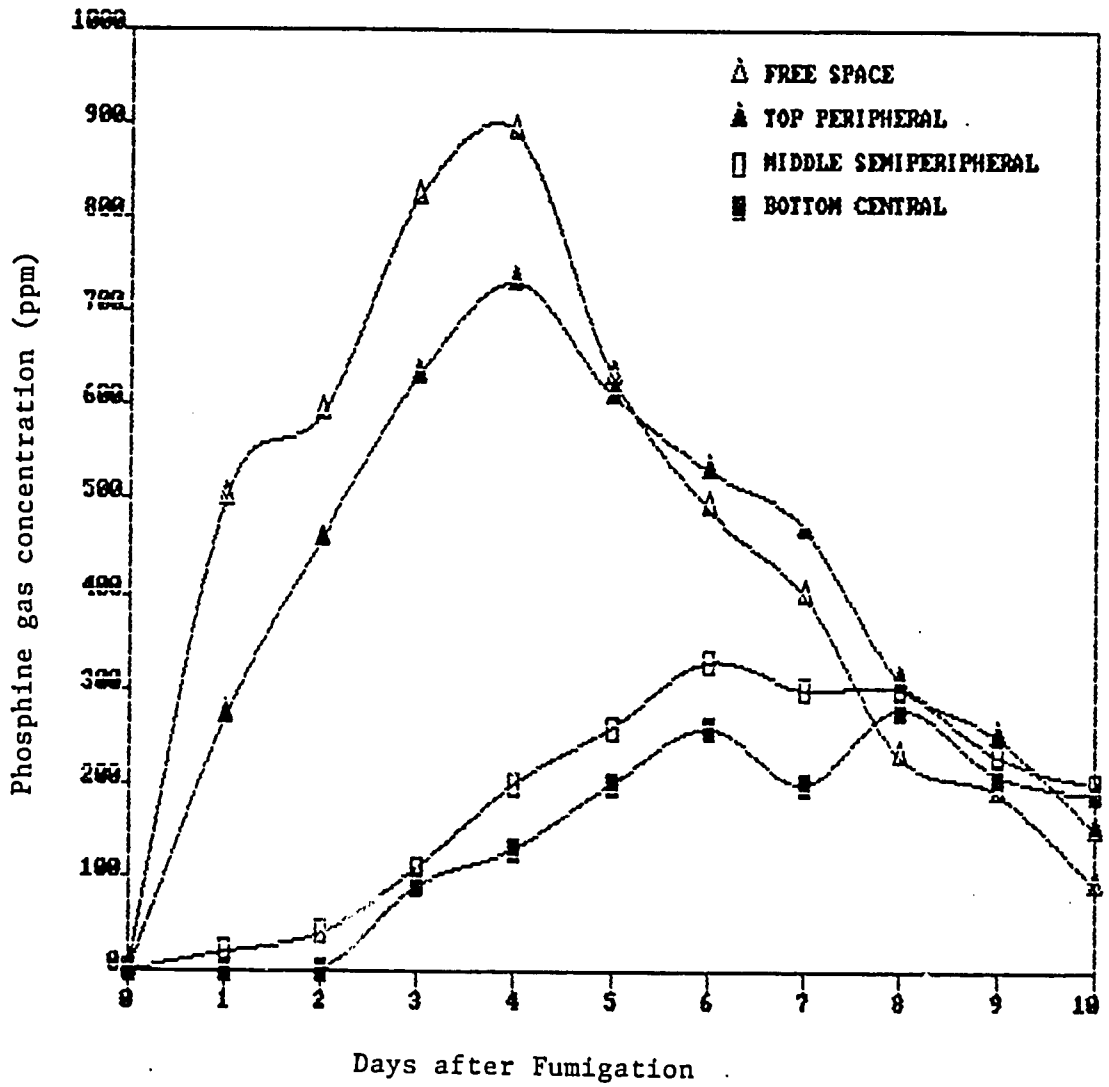

Fig. III. Phosphine gas concentration at various positions by using multiple dose of AlP tablets in house-type godown No. 5.

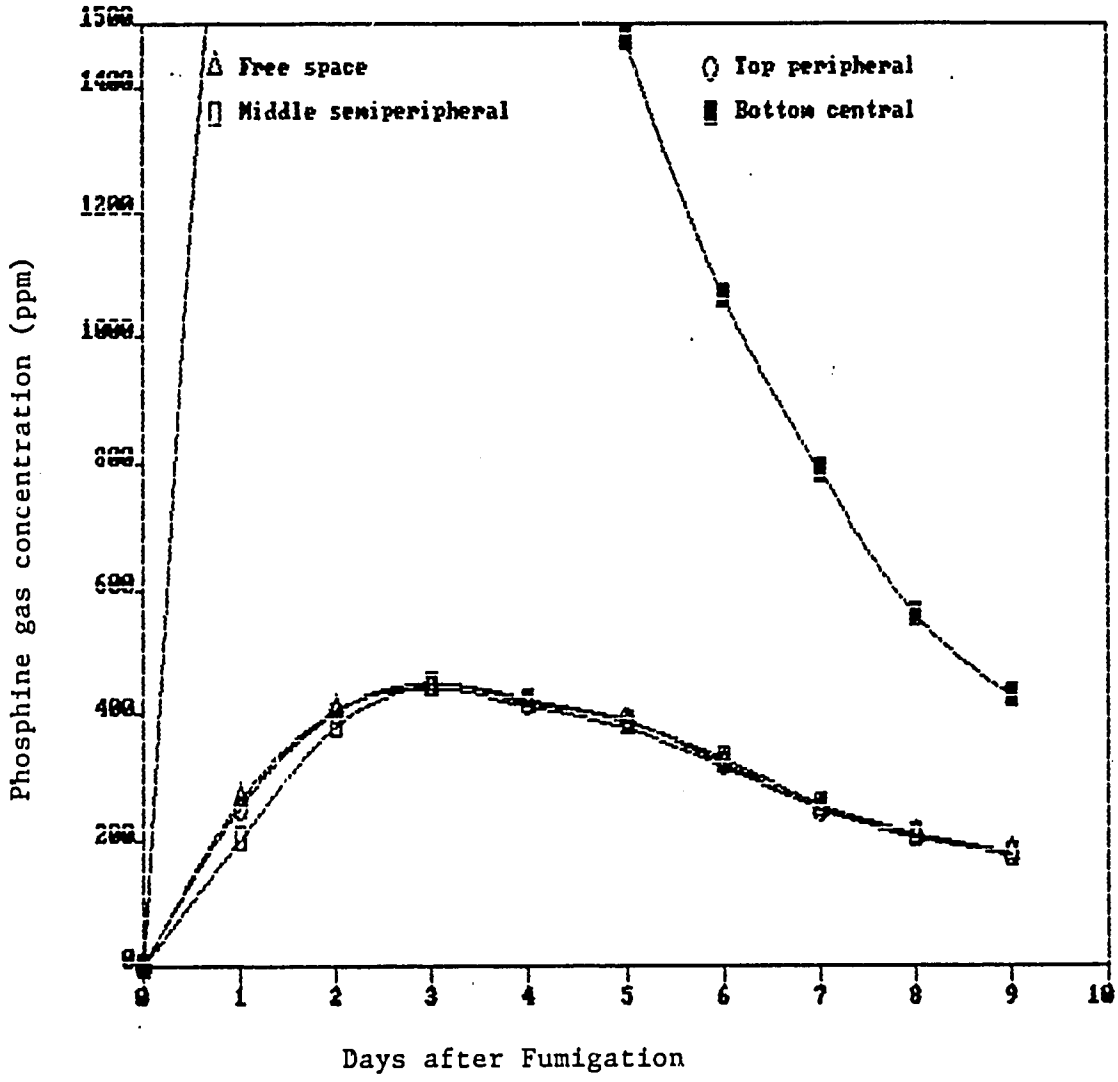

Fig. IV. Phosphine gas concentration at various positions by using dosing pipes for AlP tablets application in house-type godown.

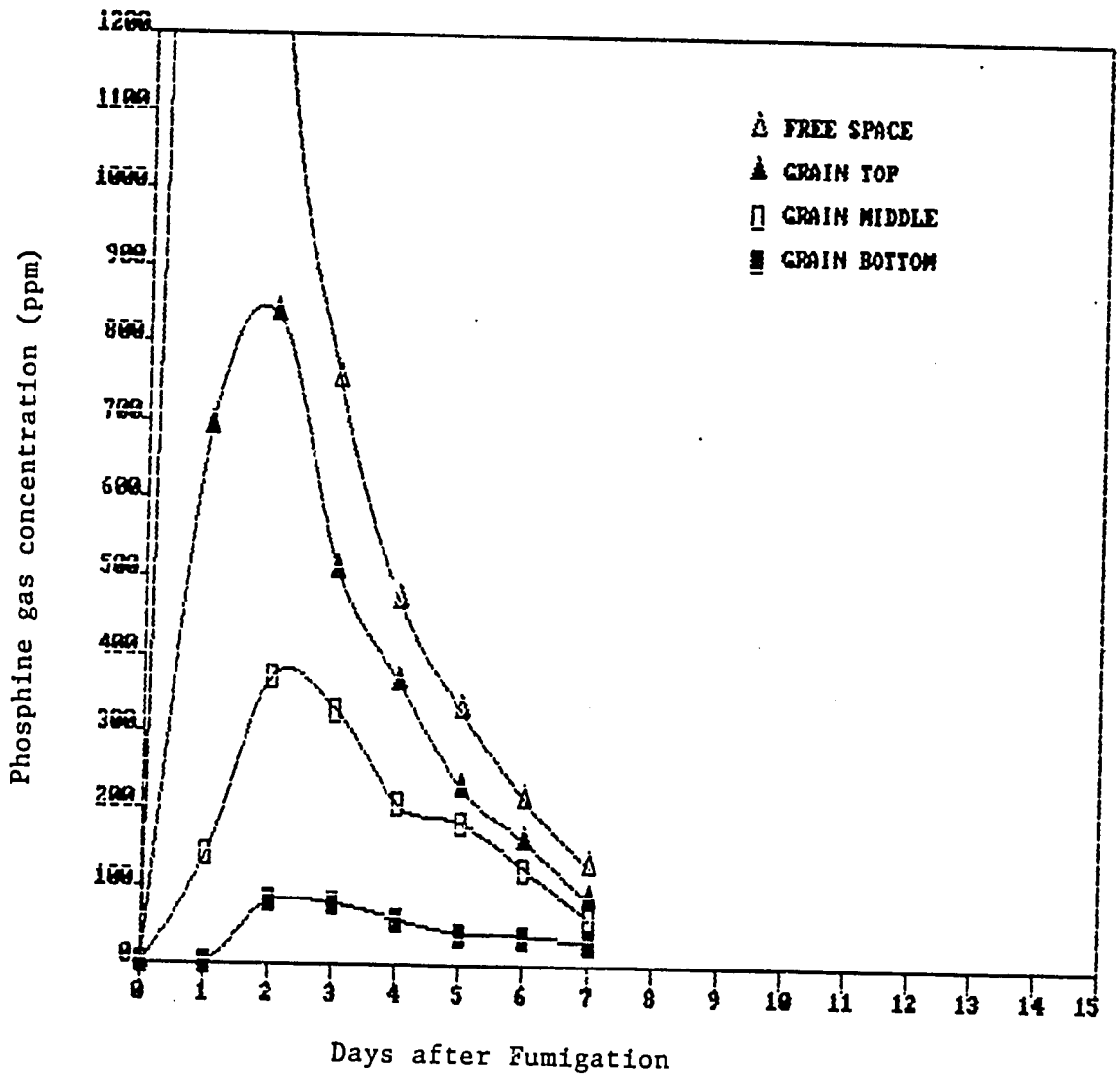

Fig. V. Phosphine fumigation of Hex bins by applying single dose of AlP tablets.

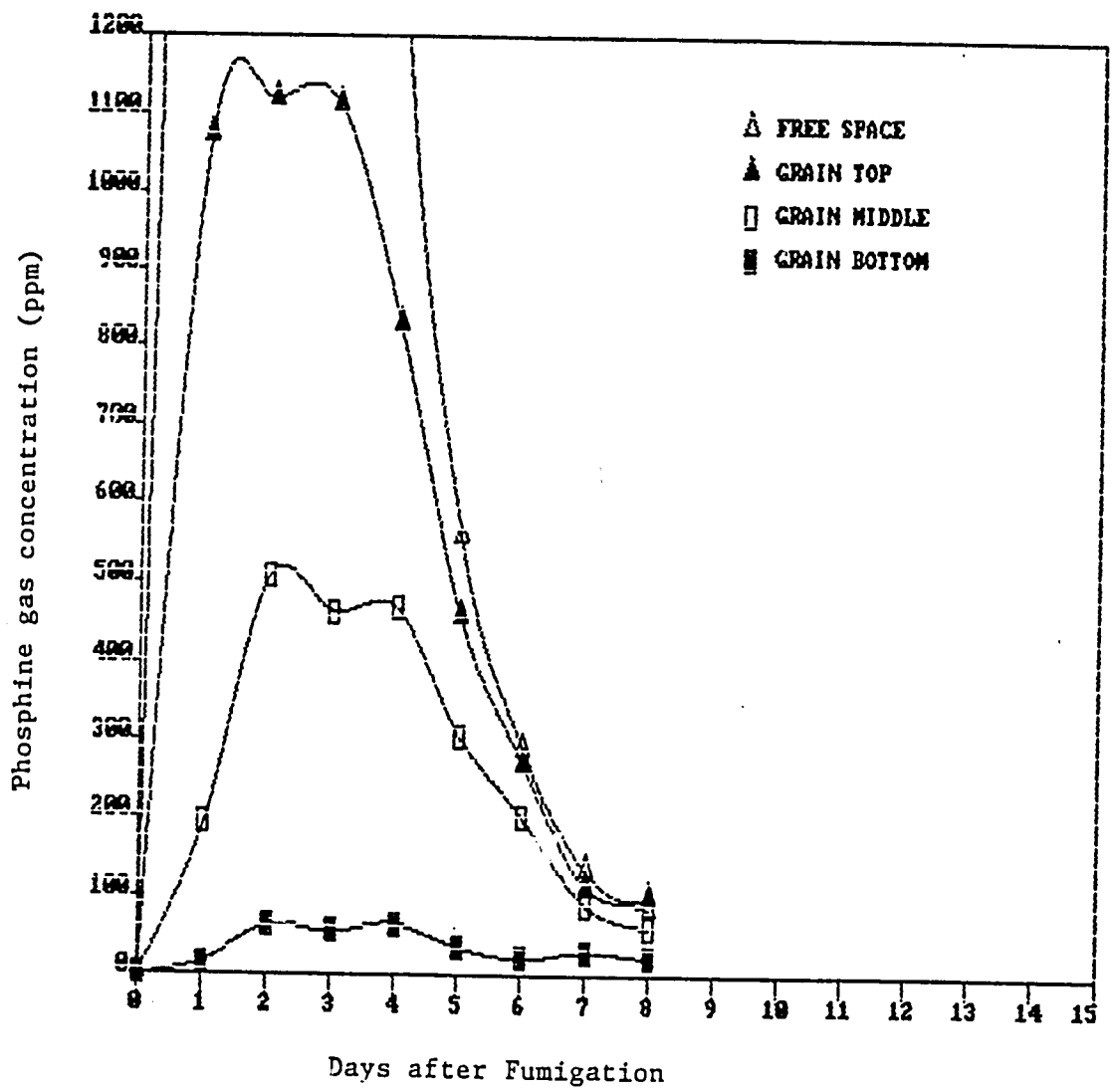

Fig. VI. Phosphine fumigation of Hex bins by using multiple dose of AlP tablets.

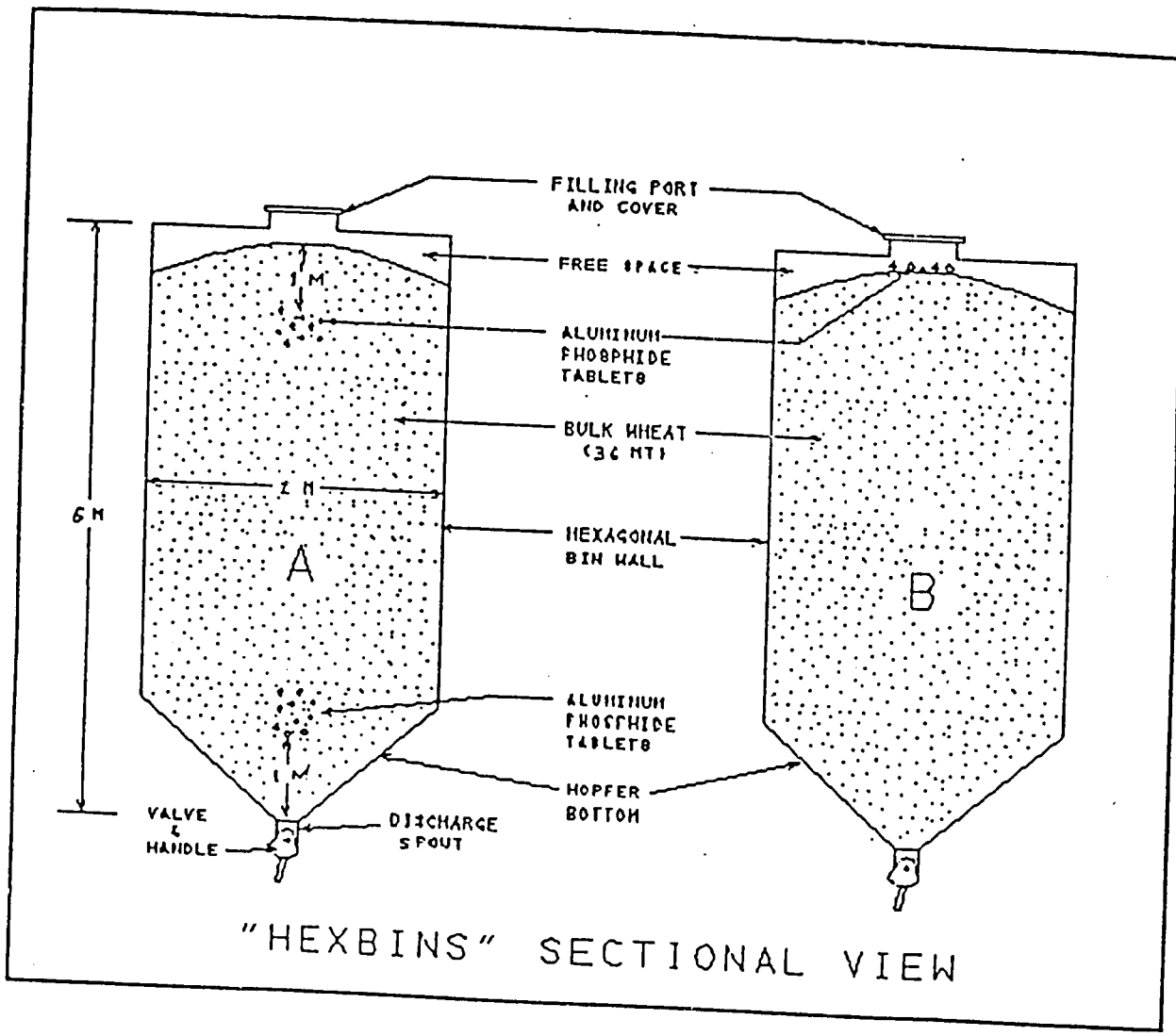

Fig. VII. Longitudinal section of a hex bin showing the position of AlP tablets in the improved method of fumigation (A) as against the conventional method (B).

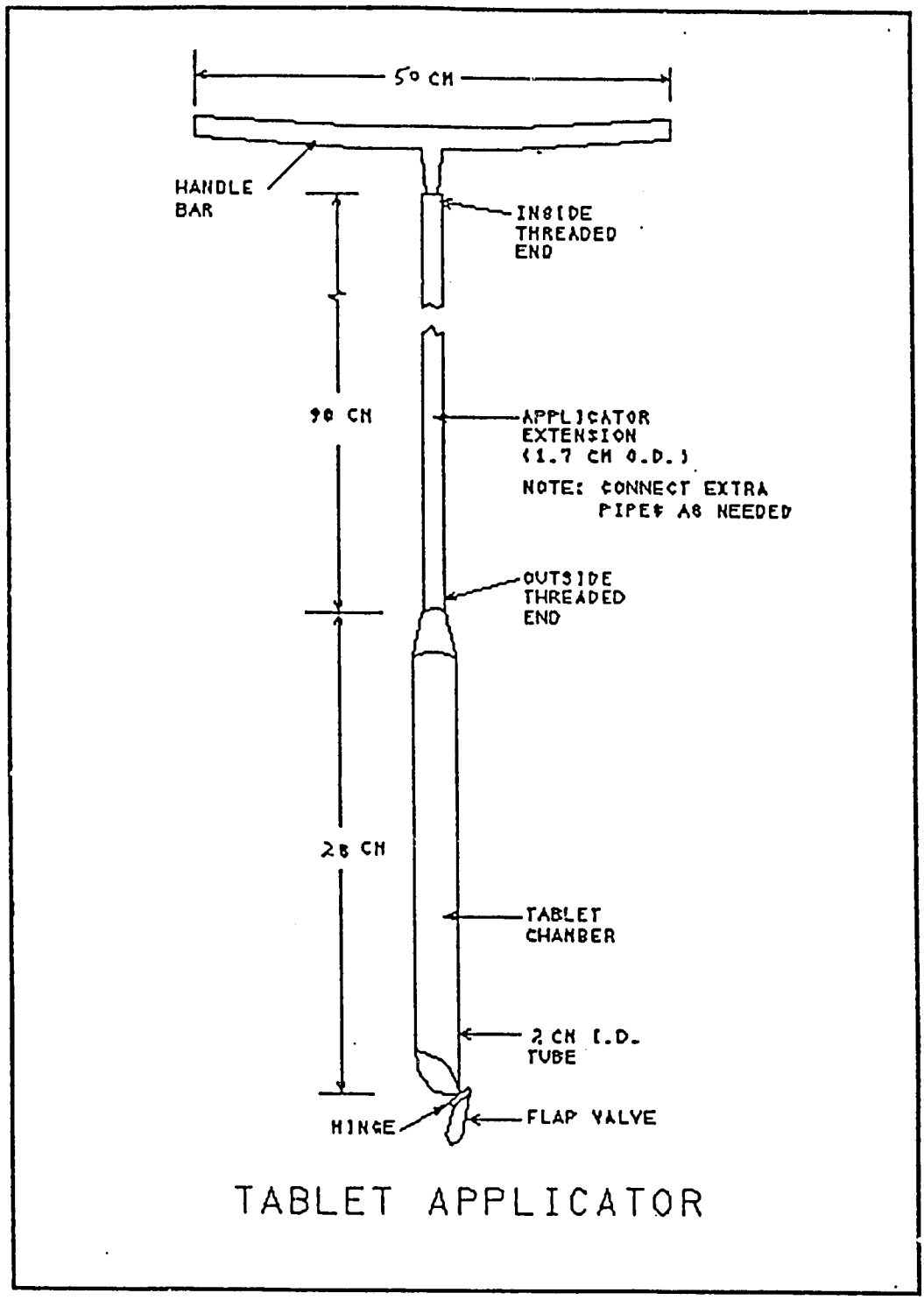

Fig. VIII. Measurements of the 'AlP tablet applicator' drawn to help its local manufacturing.

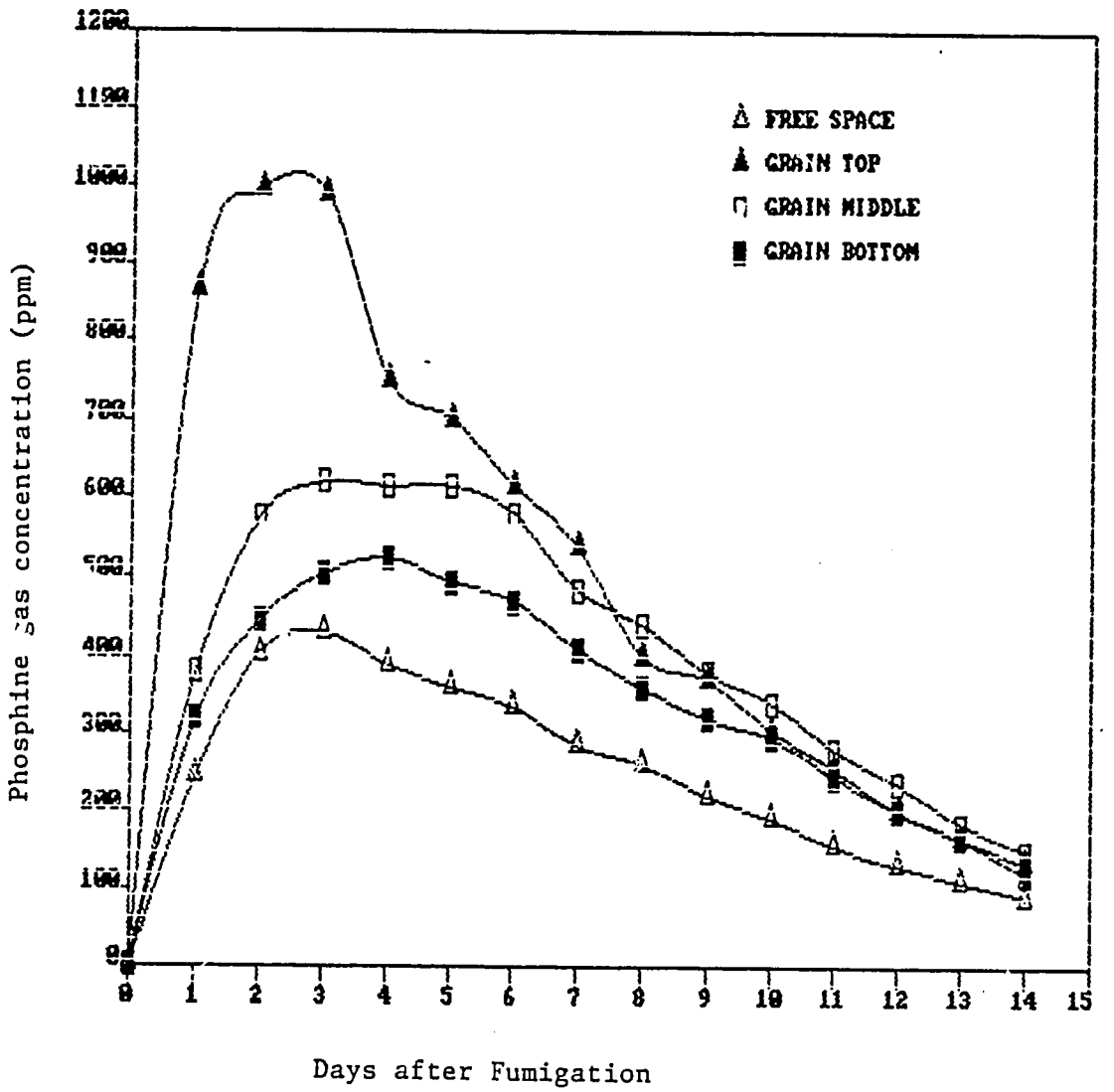

Fig. IX. Phosphine fumigation of Her bins by using improved method of AlP tablets application.

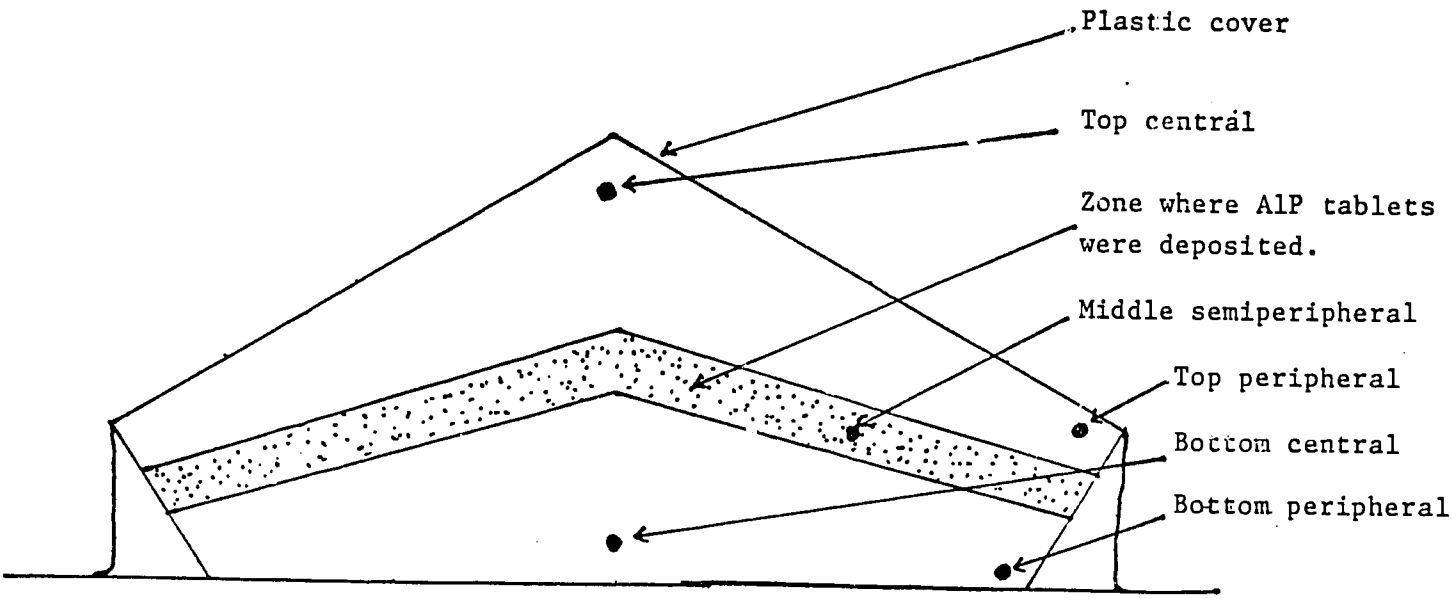

Fig. X. Cross section of a open bulkhead showing the zone where AlP tablets were deposited and the points for phosphine gas monitoring.

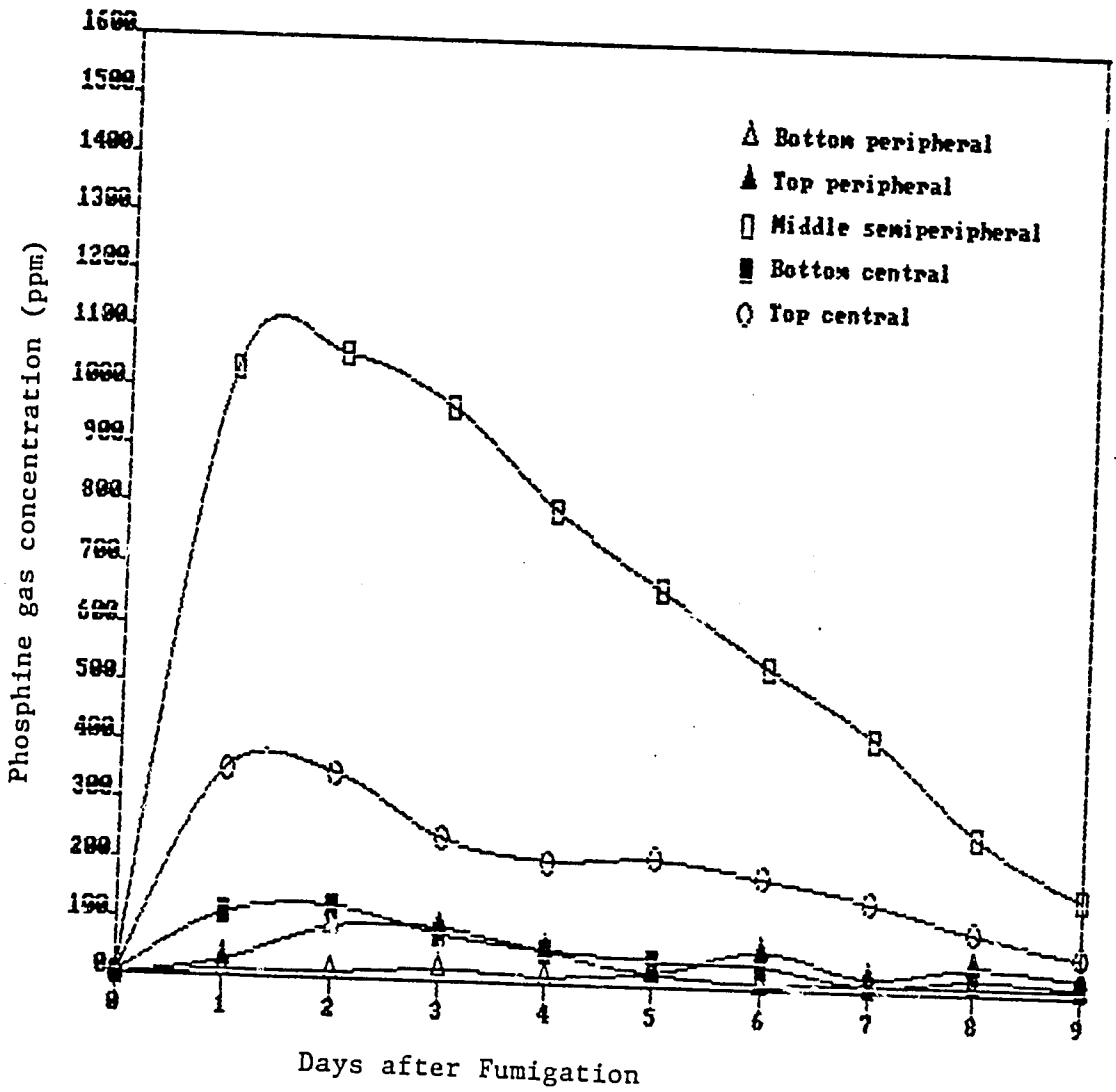

Fig. XI. Phosphine gas concentration in bulk wheat loaded open bulkhead (control i.e covered with tarpauline) at Depalpur.

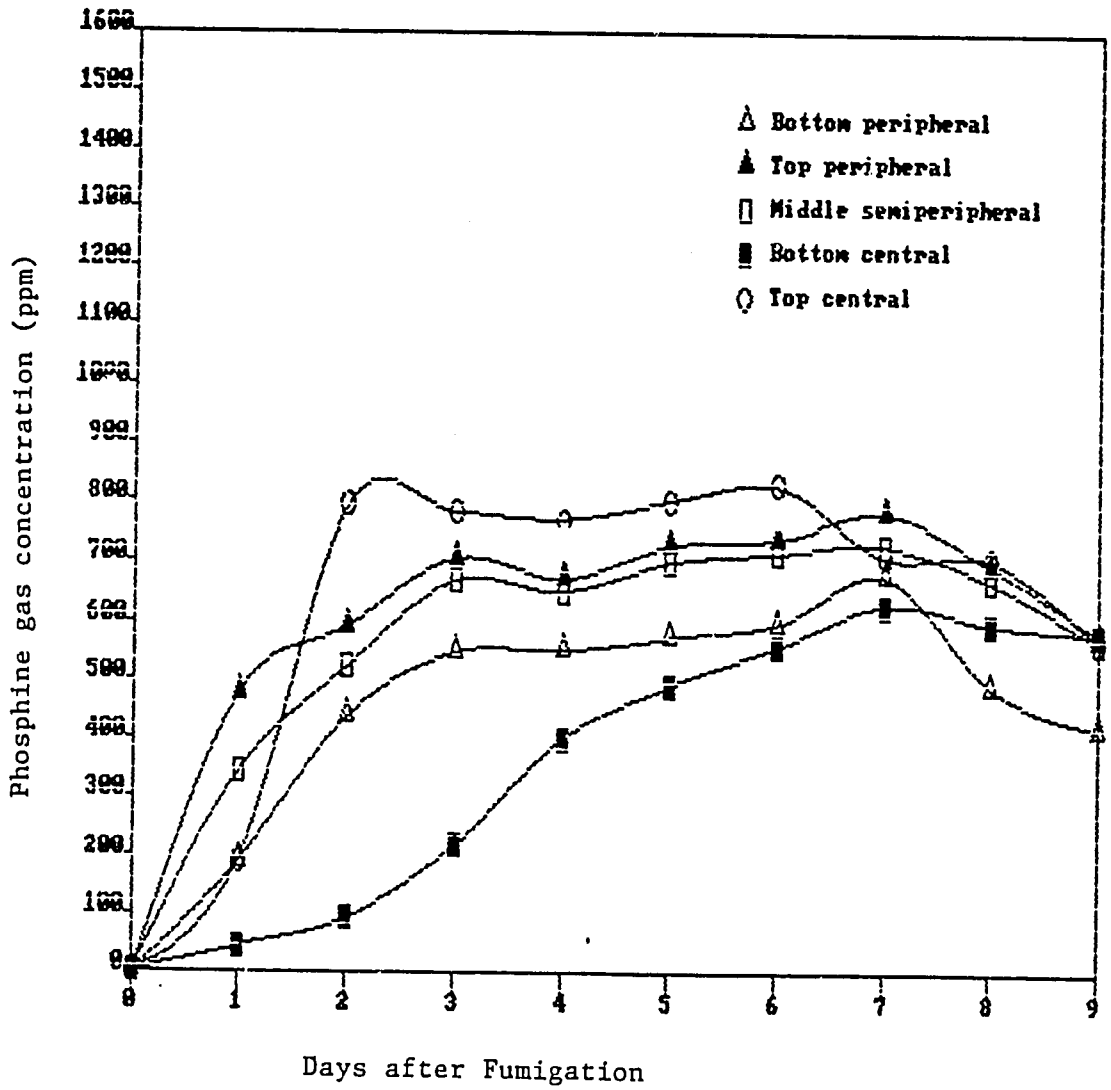

Fig. XII. Phosphine gas concentration in bulk wheat loaded open bulkhead at Depalpur. (No. 1).

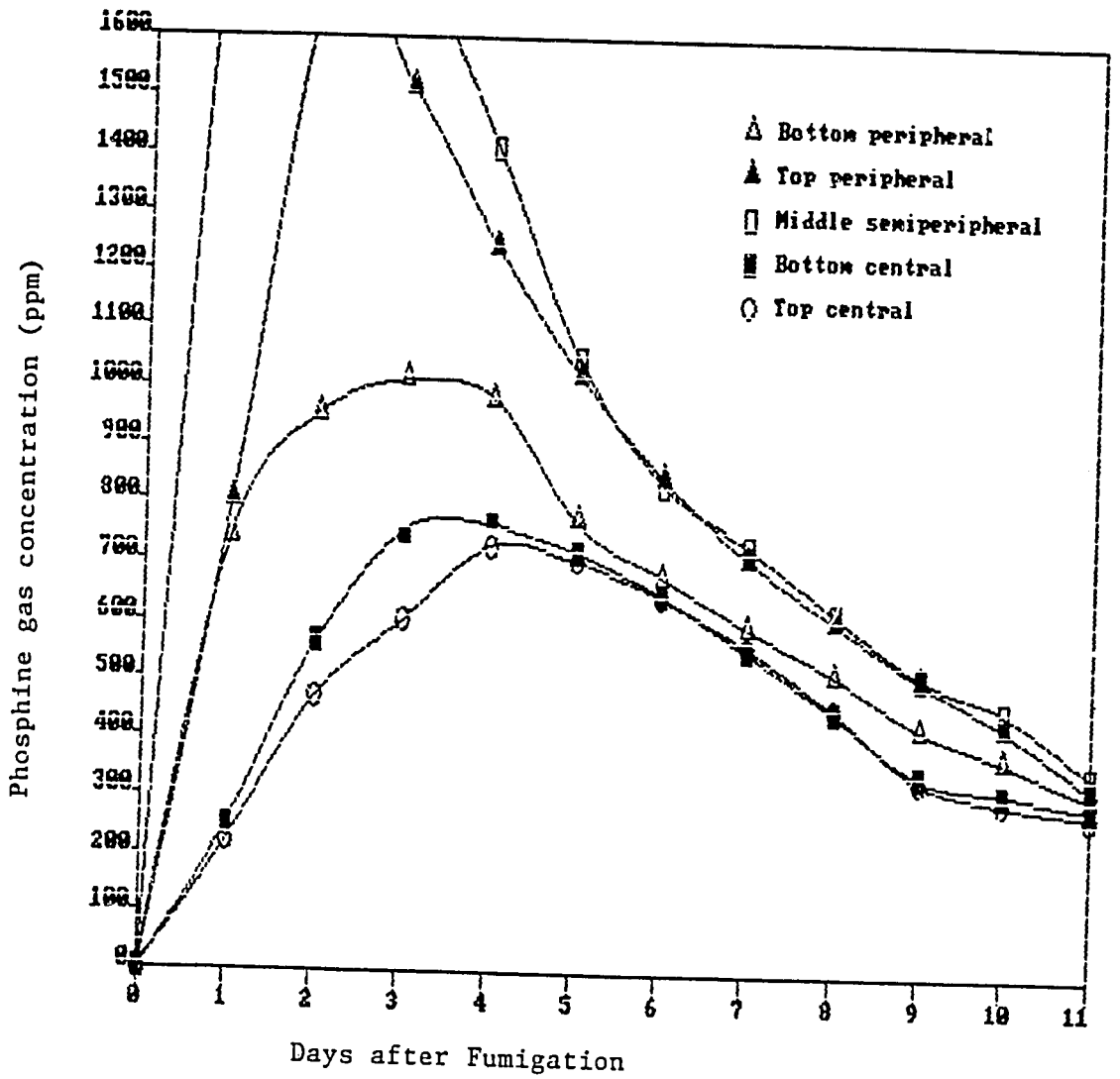

Fig. XIII. Phosphine gas concentration in bulk wheat loaded open bulkhead at Depalpur (No. 2).

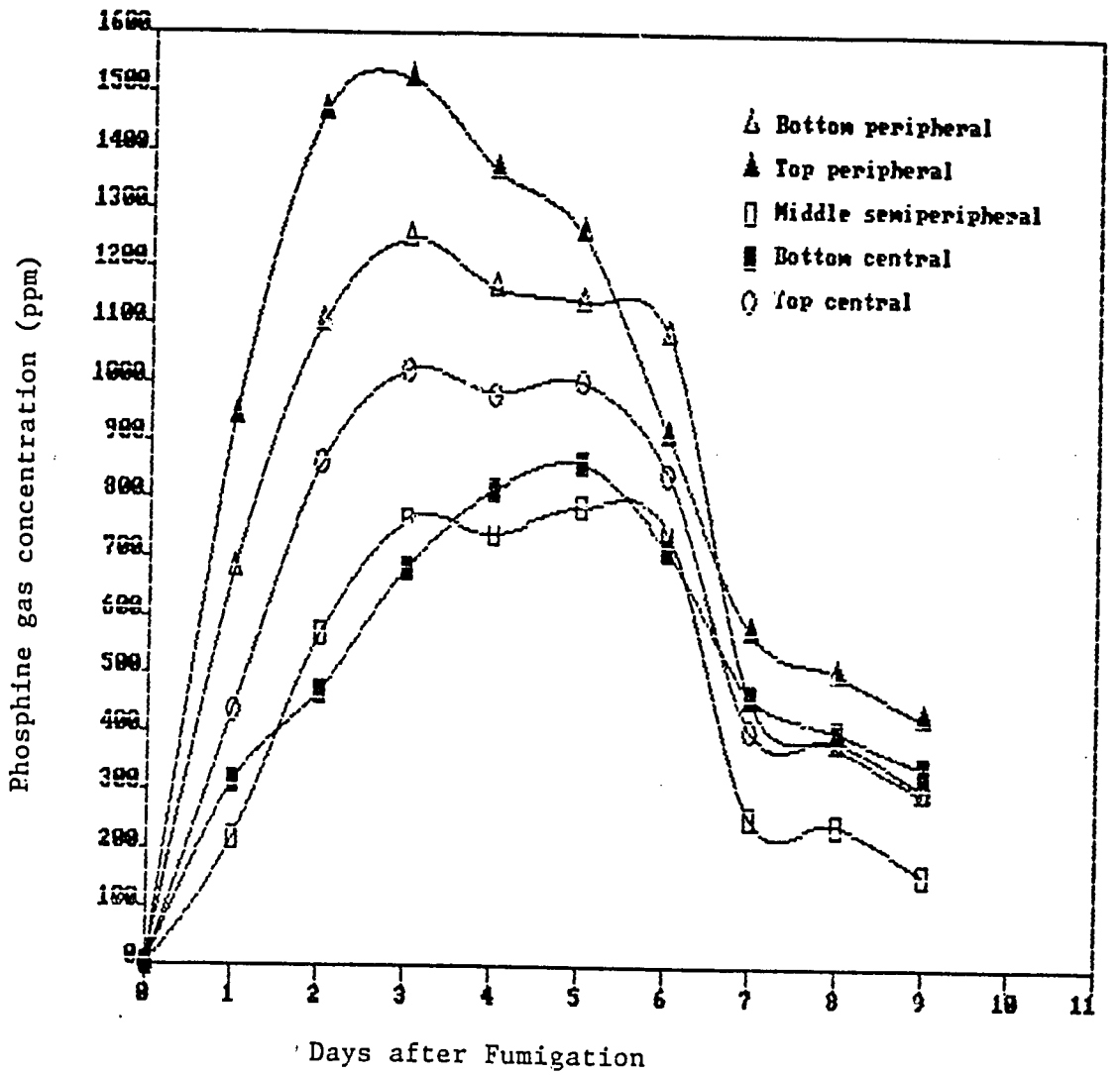

Fig. XIV.. Phosphine gas concentration in bulk wheat loaded open bulkhead at Okara.

PERSISTENCE OF PERMETHRIN, PRIMIPHOS METHYL, AND CHLORPYRIPHOS METHYL INSECTICIDES IN WHEAT STORED UNDER SIMULATED ENVIRONMENTAL CONDITIONS

By

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ABSTRACT

Procedures are described for determining the persistence of permethrin, primiphos methyl, and chlorpyriphos methyl insecticides applied directly to wheat grains and stored at two moisture contents and at four different temperatures in the laboratory. This was done with a view to simulate different climatic zones of Pakistan. Samples of treated wheat were withdrawn from storage at regular intervals, ground to a coarse powder, extracted with suitable solvents, cleaned up, and finally, analyzed for residues by gas-liquid chromatography using thermionic specific and electron capture detectors. The decline in concentration of active ingredients of the three insecticides was maximum at 40°C and 13% moisture content whereas it was minimum at 25°C and 10% moisture content.

Amongst the three products, permethrin was found to be the most persistent, followed by primiphos methyl, while chlorpyriphos methyl was the least persistent.

INTRODUCTION

Wheat is one of the most important cereal crops of Pakistan. It constitutes the basic food for most of the people and occupies more farm land than any other crop. Despite increases in wheat production made in recent years, Pakistan is not producing enough wheat to meet the needs of the rapidly increasing population. It is, therefore, necessary to strive harder to improve this situation. In this connection, a National Commission on Agriculture was set up in April 1986, which submitted its report in 1988 [1]. The Commission has recommended several measures and incentives to raise the growth rate in Agriculture to 5% per annum.

It is conservatively believed that nearly 10% of the food grains are annually destroyed in Pakistan by a variety of insect pests. For protection of wheat grain during storage, fumigation by phosphine is very common but recent reports of emergence of phosphine resistant strains of stored grain pests have prompted active research in the area of bioefficacy evaluation of newer grain protectant insecticides.

Several organophosphates and pyrethroids, alone or in combination, have been evaluated for recommendation as useful replacements against a range of stored grain pests [2-7] but their increasing use has necessitated studies on persistence which involves efficient means of pesticide residue determination of newer compounds. Many researchers have worked on the residual toxicity and persistence of grain protectants on wheat grains [8- 11]. Masud and Zakai [12] determined persistence of malathion and fenitrothion insecticides in treated wheat grains stored under laboratory conditions. Gas chromatographic analyses of samples revealed that malathion at fortification levels of 16 and 24 ppm and fenitrothion at four, eight, and 12 ppm have been found to persist in the grain for eight to ten and 18 to 20 months respectively.

Present studies were aimed at developing a suitable analytical methodology for multiple pesticide residues of three insecticides, namely, permethrin, primiphos methyl (Actellic), and chlorpyriphos methyl (Reldan) in wheat grains and determination of their persistence when applied as protectants directly to wheat of two different moisture contents and stored at four different temperatures in the laboratory. These conditions were chosen to simulate different environmental conditions of Pakistan. Results of residue determinations are presented in this paper.

MATERIALS AND METHODS

1. Wheat Grain

Fresh wheat was procured from Distt. Thatta, Sind. Prior to use, the grain was cleaned of dust, extraneous plant parts, and other foreign materials to ensure uniformity. It was thereafter fumigated with phosphine for one week to make it pest free. The fumigated grain was then exposed to the atmosphere for 24 hours to remove phosphine gas.

2. Moisture Adjustment

Laboratory evaluations were carried out at 10% and 13% moisture contents. Initial moisture content of fresh wheat determined by standard ISO air oven method [13] was 10.6%. 30 Kg wheat was taken for each moisture content. For adjustment at 13% moisture content, calculated amount of water was added to grain in 5 Kg glass jars which were then sealed and tempered according to the method of Winks [14]. One week was considered sufficient for tempering. For adjustment at 10% moisture content, wheat was sun dried.

3. Grain Protectant Insecticides

Three insecticides for laboratory evaluation, namely; permethrin (Coopex) 10/50 grain protectant containing 10%w/v permethrin and 50%w/v piperonyl butoxide, primiphos methyl (Actellic) 50%w/v EC, and chlorpyriphos methyl (Reldan) 21.8%w/w EC were supplied by M/s. Wellcome (Pak) Ltd., ICI (Pak) Ltd., & Dow Chemicals Pacific (Pak) Ltd., respectively. The grain was treated at the recommended dosages of 2mg/kg, 4mg/kg and 10mg/kg respectively.

4. Insecticide Admixing

Three Kg lots of wheat at each moisture content and for each temperature were treated with each the above-mentioned insecticides. Three replicates for each insecticide and each moisture content were treated in the following manner:

> Recommended dosage of each insecticide was separately diluted with 4ml distilled water and applied to approx. 1cm thick layer of wheat in a 68 x 46 x 9cm galvanized iron tray in the form of a fine spray using a Quickfit spray atomizer. The contents were transferred to glass jars & tumbled vigorously for approximately 20 minutes.
>
> Control lots of wheat for each moisture content and for each temperature were treated in a manner analogous to treated wheat but using only water.

5. Sample Storage

For sample storage, 1 Kg glass jars were used. Prior to use, they were properly cleaned, dried, and labelled. Treated and control wheat samples were stored in sealed glass jars at 25, 30, 35, and 40°C in different ovens. A wheat sample (800g) was placed in each jar for subsequent periodic sub-sampling.

6. Sampling Scheme

Sub-samples have been taken at the following intervals of time after treatment:

0, 1, 2, 3, and 4 weeks, and thereafter at monthly intervals up to 12 months. Prior to sampling, each lot of wheat was thoroughly mixed and then nearly 50 mg were removed from each glass jar for residue analysis. The sub-samples were properly packed in polythene bags, sealed, & deep frozen at -20°C for subsequent residue analysis.

7. Residue Determination

Each sub-sample was analyzed for residues in triplicate along with control samples to check reproducibility of results. In order to economize cost and time, a modified Becker procedure for organophosphorus pesticide residues in grain [15] was further modified in our laboratory to make it workable for permethrin (a pyrethroid) as well. Details of procedures employed are given hereunder:

7.1. Apparatus

i) Chromatographiccolumn, 450 x 25mm i.d. fitted with pyrex glass stopcock.

ii) Separatory funnel, glass stoppered, Pyrex, 1 litre cap.

iii) Grinder, hand driven.

iv) Filter paper, Whatman No. 542.

v) High speed Waring blender.

vi) Rotary Vacuum evaporator.

vii) Griffin Flask Shaker, Griffin & George, England.

viii) GLC apparatus: Varian AG GC-3600 fitted with thermionic specific (TSD) and Ni electron capture (ECD) detectors for Actellic, Reldan, and permethrin respectively. GLC columns and operating parameters were chosen which achieved optimum balance between sensitivity and degree of resolution with good symmetrical peaks emerging with reasonable retention times. The following operating parameters were employed for the studied compounds on two different detection systems:

Actellic and Reldan: Glass column 1 meter long x 2mm i.d. packed with 3% OV-210 on 80-100 mesh Chromosorb W-HP. Temperatures: Injector 220°C, column oven 190°C detector (TSD) 25°C. Attenuation 64, range 12, Bead current 3.2 Amp., Gas flows: Nitrogen carrier gas 30ml/minute, Hydrogen 54ml/minute, and Air 175ml/minute. The detector was linear in the range of 0.01-1.0 ng and 0.01-2.0 ng for Actellic & Reldan insecticides, respectively.

Permethrin: Glass column 2 metres long x 2mm i.d. packed with a mixture

of 1.5% OV-17 + 1.95% OV-210 on 80-100 mesh Chromosorb W-HP. Temperatures; Injector 250°C, column oven 230°C, detector (ECD) 280°C. Attenuation 32, range 10; Gas flow: Nitrogen (carrier) 30ml/minute. The detector was linear in the range of 0.01 to 1 ng.

Prior to use, each column was conditioned for 24 hours under a slow stream of nitrogen at temperatures 50°C higher than their working temperatures.

Under the above operating conditions, retention times of pesticides were as follows:

Actellic 2.2min., Reldan 1.9min., and Permethrin 10.9min.

The equipment was used in conjunction with data system Varian - DS-651 and thinkjet printer (Hewlett Packard, USA).

7.2. Reagents

i) Acetone, toluene, dichloromethane, & n-hexane. All solvents were AR grade and distilled before use.

ii) Extraction solvent: water - acetone (1+8).

iii) Eluting solvent mixture: toluene - dichloromethane (1:5). Acetone was excluded from the procedure [15] because, with its use, starch was not retained at the column cleanup step. It was necessary to completely remove starch which interferred with subsequent analysis.

iv) Silica gel: For column chromatography (Merck No.7734), used without pretreatment.

v) Activated charcoal (Merck No.2183).

vi) Sodium chloride, AR grade, saturated solution.

vii) Sodium sulphate, anhydrous, AR grade. Heated at 400°C for 4 hours, cooled in a desiccator, and transferred to a suitable bottle.

7.3. Extraction

The sample of wheat grain was ground to a coarse powder. 15g of the prepared sample was homogenised with 75ml of extraction solvent in a blender for one minute. The contents were transferred to a 250ml glass stoppered conical flask, shaken on an electrical shaker for three hours and then filtered through Whatman No. 542 filter paper. The residue was washed twice with 15+10ml portions of extraction solvent. Combined the three filtrates and discarded the residue. The combined filtrate (extract) was transferred to a one litre separatory funnel, added 150ml of water, 10ml of saturated sodium chloride solution and 25ml of dichloromethane. The contents were shaken for two minutes and the dichloromethane layer was separated. Repeated the process twice with two 25ml portions of dichloromethane. Combined the dichloromethane layers. 10gm anhyhrous sodium sulphate were added to it and allowed to stand for 30 minutes. Filtered the dry

extract through a fluted filter paper, rinsed the container and filtered with three more 10ml portions of dichloromethane. Combined the filtrates and reduced its volume to approximately 10ml in a rotary evaporator.

7.4. Cleanup

Preparation of a chromatographic column. A slurry of a mixture of 5g silica gel and 15ml eluting solvent was prepared and poured into a column pre-charged with 1ml of dichloromethane. The mixture was allowed to settle and excess of the solvent was run through the column. Thoroughly mixed 15gm silica gel with 1g activated charcoal in a 100ml beaker and slowly stirred in 35ml of eluting solvent. While stirring, poured the charcoal-silica gel mixture on to the silica layer in the column, at first slowly and then the remainder rapidly. During this process, the tap was left open to obtain compact column packing and allowed the eluting solvent to run off until its level stood approximately 2cm above the column packing and then covered it slowly with about 5gm sodium sulphate. Washed the column with 50ml of eluting solvent.

Column chromatography. The concentrated extract was transferred quantitatively into the prepared column, rinsing the flask thrice with a small volume of dichloromethane. Collected all the eluate from the moment of transfer in a 250ml Erlenmeyer flask. Eluted with 200ml eluting solvent. The eluate was concentrated to about dryness in a rotary vacuum evaporator and the residue was taken-up in a small volume of n-hexane and quantitatively transferred to a 10ml calibrated flask and diluted as desired for gas chromatography.

7.5 Gaschromatography

Each cleaned up sample extract was analyzed by gas chromatography along with its insecticide standard in n-hexane using 1ul injections. Results were evaluated by comparing the peak heights of sample extracts with those of relevant insecticide standards. Three sample injections were carried out on each extract to check reproducibility of results. Untreated control samples processed in an analogous manner did not show any interfering peak that might be attributed to the studied compounds.

RESULTS AND DISCUSSION

Prior to these studies, the efficiency of analytical procedures was evaluated in model experiments with procured wheat. Fifteen grams of this material was coarsely ground and spiked with each of the three insecticides separately at levels of 0.01 to 10ppm. Extraction and cleanup was conducted immediately afterwards. Subsequent gas chromatographic analyses revealed that recoveries of permethrin, primiphos methyl, and chlorpyriphos methyl were in the range of 80-97% at fortification levels of 0.01 ppm for the three insecticides. These recovery results, therefore, compared with wheat treated 24 hours earlier with studied pesticides as according to Desmarchellier (16), recoveries from fortified samples are sometimes not a reliable guide to recoveries of aged deposits. In both the cases, results compared satisfactorily. The methods are efficient, sensitive, and reliable.

Loss of each studied insecticide with time in relation to different temperatures and moisture contents is presented in Tables I to III. Each figure in the table is the mean pesticide residue of three replicates and is presented with standard error. Loss of three compounds under the given conditions after one year's storage is depicted in Figure 1.

It is evident from this data that there is a gradual loss of each insecticide at increasing temperatures and moisture contents (m.c.). It is minimum at 250°C and 10% m.c. and maximum at 40°C and 13% m.c. However, two moisture contents have not played any significant role in the breakdown of insecticides. Loss of active ingredient of each insecticide from treated wheat is discussed separately hereunder.

Permethrin. From an average zero day figure of 2.31 ppm, the residue levels were 1.02, 0.47, 0.24 and 0.07 ppm at the end of the 16th sampling of treated wheat at 25, 30, 35, & 40°C respectively at 10% M.C. while at 13% M.C., from an initial treatment dosage of 2.20 ppm, the levels were 0.91, 0.48, 0.24 and 0.03 ppm respectively after the same period of storage.

Actellic. At 10% moisture content, from an average treatment dosage of 4.08 ppm on the zero day, the residue levels at 25, 30, 35 and 40°C at the end of the 16th sampling fell down to 0.32, 0.05, traces, and 0.00 ppm respectively, while at 13% moisture content, from an average zero day figure of 4.27 ppm, the levels were 0.28, 0.03, traces, and 0.00 ppm respectively, after the same period of storage.

Reldan. At 10% moisture content, from an average treatment dosage of 10.29 ppm on the zero day, the residue levels at 25, 30, 35 and 40°C at the end of the 16th sampling (i.e., 12 months after storage) diminished to 0.19, 0.08, 0.00 and 0.00 ppm respectively while at 13% moisture content, from an average treatment dosage of 10.03 ppm, it decreased to 0.19, 0.02, 0.00 and 0.00 ppm after the same storage period.

CONCLUSION

On the basis of these studies, it can be safely concluded that permethrin is the most persistent of the three followed by Actellic and Reldan. Actellic & Reldan residues declined quickly at 40°C but slowly at 25°C. Therefore, the three insecticides may be used in the order: permethrin > primiphos methyl > chlorpyriphos methyl depending upon the period of storage. Depending upon the nature or intensity of stored grain pests and period of storage, the insecticides may be safely applied at a slightly higher dosage rate than applied by the authors in order to achieve satisfactory control.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Richard C.Maxon, Chief of Party, USAID/STDT/FSM project for providing equipment and financial support for the project. The authors are deeply indebted to Prof. Dr. Irshad Ahmed Khan Afridi, Research Supervisor of Miss Zahida Parveen for his valuable suggestions during the course of these investigations. Authors are also grateful to M/s. Nafis- ul-Alam & Razi-ul-Haque Farooqi, Research Fellows of the project, for practical assistance.

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TABLE-I

RESIDUE LEVELS (ppm) OF PERMETHRIN ON WHEAT AT FOUR DIFFERENT STORAGE TEMPERATURES AND TWO MOISTURE CONTENTS AFTER INDICATED PERIODS OF SAMPLING

Sl. No.	Sampling after treatment	MOISTURE CONTENT 10% Storage temperature (°C) 25	30	35	40	13% Storage temperature (°C) 25	30	35	40
1.	0 day*	2.31 ± 0.1	-	-	- 2.20 ± 0.06	-	-	-	
2.	1 week	2.26 ± 0.02	2.08 ± 0.03	1.94 ± 0.04	1.85 ± 0.03	2.18 ± 0.05	2.10 ± 0.03	2.01 ± 0.03	1.79 ± 0.02
3.	2 weeks	2.12 ± 0.05	1.96 ± 0.02	1.89 ± 0.03	1.83 ± 0.02	2.07 ± 0.02	1.91 ± 0.02	1.91 ± 0.04	1.75 ± 0.02
4.	3 weeks	1.95 ± 0.04	1.96 ± 0.01	1.87 ± 0.02	1.82 ± 0.02	1.98 ± 0.07	1.88 ± 0.02	1.87 ± 0.02	1.72 ± 0.02
5.	4 weeks	1.86 ± 0.03	1.98 ± 0.03	1.79 ± 0.01	1.73 ± 0.01	1.99 ± 0.06	1.88 ± 0.03	1.87 ± 0.02	1.72 ± 0.02
6.	2 months	1.62 ± 0.03	1.54 ± 0.04	1.49 ± 0.04	1.31 ± 0.02	1.68 ± 0.06	1.68 ± 0.07	1.53 ± 0.03	1.29 ± 0.01
7.	3 months	1.58 ± 0.01	1.40 ± 0.02	1.21 ± 0.03	0.94 ± 0.04	1.62 ± 0.03	1.34 ± 0.02	1.18 ± 0.01	0.88 ± 0.004
8.	4 months	1.55 ± 0.02	1.38 ± 0.01	1.19 ± 0.01	0.86 ± 0.02	1.53 ± 0.04	1.35 ± 0.01	1.11 ± 0.004	0.82 ± 0.02
9.	5 months	1.48 ± 0.02	1.34 ± 0.01	1.13 ± 0.01	0.81 ± 0.01	1.47 ± 0.01	1.30 ± 0.01	1.07 ± 0.03	0.77 ± 0.03
10.	6 months	1.42 ± 0.01	1.31 ± 0.01	1.05 ± 0.04	0.74 ± 0.01	1.41 ± 0.01	1.26 ± 0.01	1.02 ± 0.02	0.72 ± 0.02
11.	7 months	1.31 ± 0.06	1.16 ± 0.06	0.98 ± 0.01	0.56 ± 0.01	1.25 ± 0.01	1.08 ± 0.004	0.93 0.01	0.47 0.004
12.	8 months	1.26 ± 0.01	1.05 ± 0.01	0.69 ± 0.01	0.43 ± 0.01	1.21 ± 0.01	1.02 ± 0.004	0.66 ± 0.01	0.34 ± 0.004
13.	9 months	1.21 ± 0.004	1.02 ± 0.01	0.65 ± 0.02	0.41 ± 0.01	1.14 ± 0.03	0.99 ± 0.004	0.59 ± 0.004	0.30 ± 0.0
14.	10 months	1.17 ± 0.01	0.92 ± 0.01	0.53 ± 0.01	0.28 ± 0.01	1.10 ± 0.02	0.83 ± 0.01	0.51 ± 0.004	0.19 ± 0.004
15.	11 months	1.12 ± 0.01	0.70 ± 0.01	0.38 ± 0.01	0.20 ± 0.0	1.04 ± 0.02	0.62 ± 0.01	0.40 ± 0.004	0.14 ± 0.004
16.	12 months	1.02 ± 0.004	0.47 ± 0.01	0.24 ± 0.01	0.07 ± 0.004	0.91 ± 0.004	0.48 ± 0.01	0.24 ± 0.01	0.03 ± 0.004

* Room Temperature

TABLE-II

RESIDUE LEVELS (ppm) OF ACTELLIC ON WHEAT AT FOUR DIFFERENT STORAGE TEMPERATURES AND TWO MOISTURE CONTENTS AFTER INDICATED PERIODS OF SAMPLING

Sl. No.	Sampling after treatment	MOISTURE CONTENT 10% Storage temperature (°C) 25	30	35	40	13% Storage temperature (°C) 25	30	35	40
1.	0 day*	4.08 ± 0.04	-	-	-	4.27 ± 0.14	-	-	-
2.	1 week	4.07 ± 0.10	4.03 ± 0.04	4.03 ± 0.03	4.01 ± 0.06	4.24 ± 0.01	4.21 ± 0.06	4.06 ± 0.01	4.04 ± 0.06
3.	2 weeks	4.04 ± 0.03	4.01 ± 0.12	3.99 ± 0.03	3.36 ± 0.08	4.08 ± 0.08	4.02 ± 0.05	4.01 ± 0.04	3.58 ± 0.13
4.	3 weeks	3.65 ± 0.01	3.55 ± 0.04	2.99 ± 0.04	2.77 ± 0.09	3.57 ± 0.14	3.41 ± 0.17	3.24 ± 0.10	2.77 ± 0.01
5.	4 weeks	3.16 ± 0.03	2.68 ± 0.06	2.49 ± 0.20	2.01 ± 0.08	3.40 ± 0.12	2.44 ± 0.04	2.28 ± 0.09	1.67 ± 0.04
6.	2 months	3.07 ± 0.02	2.36 ± 0.02	1.32 ± 0.02	0.80 ± 0.02	3.01 ± 0.03	2.24 ± 0.04	1.12 ± 0.04	0.61 ± 0.01
7.	3 months	2.42 ± 0.04	1.74 ± 0.04	1.23 ± 0.01	0.22 ± 0.01	2.37 ± 0.02	1.68 ± 0.02	0.97 ± 0.02	0.20 ± 0.01
8.	4 months	2.12 ± 0.02	1.08 ± 0.03	0.93 ± 0.02	0.18 ± 0.01	2.05 ± 0.04	1.11 ± 0.01	0.85 ± 0.01	0.14 ± 0.01
9.	5 months	1.91 ± 0.03	0.77 ± 0.04	0.65 ± 0.02	0.15 ± 0.01	1.72 ± 0.02	0.76 ± 0.02	0.53 ± 0.01	0.12 ± 0.01
10.	6 months	1.61 ± 0.004	0.60 ± 0.02	0.53 ± 0.02	0.13 ± 0.01	1.57 ± 0.02	0.56 ± 0.01	0.41 ± 0.02	0.10 ± 0.02
11.	7 months	1.03 ± 0.01	0.44 ± 0.01	0.37 ± 0.02	0.08 ± 0.0	0.97 ± 0.02	0.39 ± 0.01	0.25 0.01	0.06 0.01
12.	8 months	0.97 ± 0.01	0.39 ± 0.004	0.23 ± 0.004	0.06 ± 0.004	0.94 ± 0.02	0.31 ± 0.01	0.20 ± 0.004	0.04 ± 0.004
13.	9 months	0.69 ± 0.02	0.27 ± 0.004	0.17 ± 0.01	0.04 ± 0.004	0.65 ± 0.02	0.24 ± 0.01	0.15 ± 0.004	0.02 ± 0.004
14.	10 months	0.51 ± 0.01	0.18 ± 0.01	0.11 ± 0.01	0.02 ± 0.004	0.45 ± 0.03	0.15 ± 0.01	0.08 ± 0.004	0.01 ± 0.0
15.	11 months	0.40 ± 0.01	0.12 ± 0.004	0.07 ± 0.01	Traces	0.37 ± 0.004	0.10 ± 0.0	0.05 ± 0.0	Traces
16.	12 months	0.32 ± 0.01	0.05 ± 0.0	Traces	NIL	0.28 ± 0.004	0.03 ± 0.004	Traces	NIL

* Room Temperature

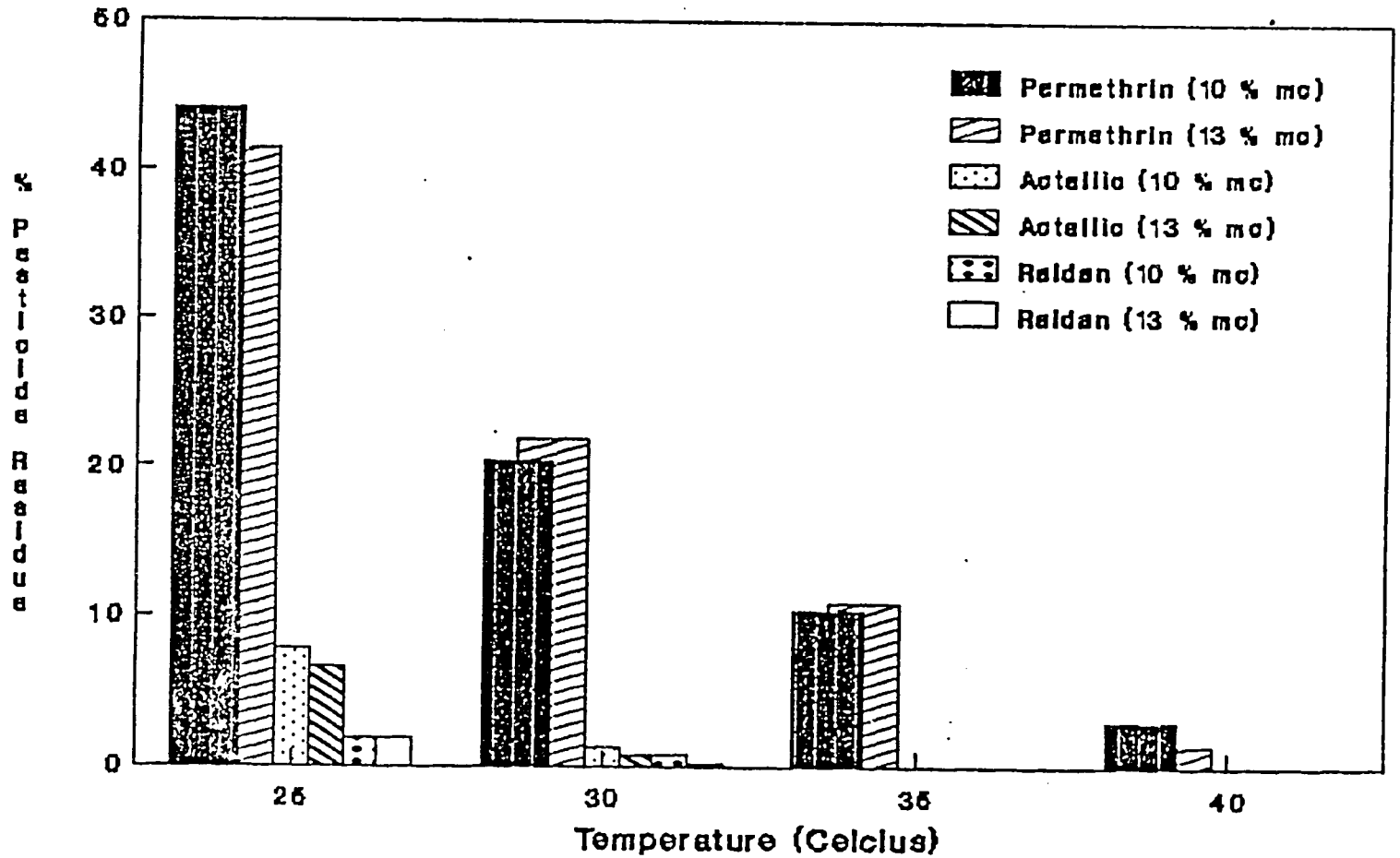
TABLE-III

RESIDUE LEVELS (ppm) OF RELDAN ON WHEAT AT FOUR DIFFERENT STORAGE TEMPERATURES AND TWO MOISTURE CONTENTS AFTER INDICATED PERIODS OF SAMPLING

Sl. No.	Sampling after treatment	MOISTURE CONTENT 10% Storage temperature (°C) 25	30	35	40	13% Storage temperature (°C) 25	30	35	40
1.	0 day*	10.29 ± 0.03	-	-	-	10.03 ± 0.04	-	-	-
2.	1 week	10.03 ± 0.18	9.94 ± 0.04	8.05 ± 0.08	5.80 ± 0.20	9.99 ± 0.09	9.27 ± 0.18	7.69 ± 0.05	6.46 ± 0.29
3.	2 weeks	9.98 ± 0.02	9.14 ± 0.10	7.71 ± 0.02	4.78 ± 0.05	9.94 ± 0.20	8.54 ± 0.03	7.11 ± 0.04	4.37 ± 0.12
4.	3 weeks	9.66 ± 0.04	5.72 ± 0.21	3.18 ± 0.04	3.06 ± 0.14	9.56 ± 0.17	5.56 ± 0.04	3.47 ± 0.04	3.28 ± 0.15
5.	4 weeks	9.39 ± 0.08	3.70 ± 0.05	1.98 ± 0.07	1.60 ± 0.09	9.34 ± 0.13	3.24 ± 0.20	1.95 ± 0.19	1.71 ± 0.04
6.	2 months	3.13 ± 0.04	2.27 ± 0.04	1.28 ± 0.004	1.10 ± 0.08	2.98 ± 0.03	1.53 ± 0.04	1.36 ± 0.04	1.16 ± 0.04
7.	3 months	1.21 ± 0.03	0.89 ± 0.04	0.41 ± 0.02	0.37 ± 0.01	1.11 ± 0.02	0.79 ± 0.02	0.37 ± 0.06	0.25 ± 0.03
8.	4 months	1.16 ± 0.004	0.69 ± 0.01	0.34 ± 0.01	0.26 ± 0.02	1.04 ± 0.01	0.68 ± 0.02	0.33 ± 0.01	0.18 ± 0.01
9.	5 months	1.13 ± 0.01	0.65 ± 0.01	0.32 ± 0.004	0.24 ± 0.02	1.02 ± 0.004	0.59 ± 0.01	0.33 ± 0.004	0.16 ± 0.02
10.	6 months	1.07 ± 0.02	0.62 ± 0.01	0.32 ± 0.004	0.20 ± 0.01	1.01 ± 0.01	0.56 ± 0.01	0.29 ± 0.004	0.11 ± 0.01
11.	7 months	0.96 ± 0.02	0.58 ± 0.004	0.26 ± 0.004	0.09 ± 0.0	0.92 ± 0.004	0.48 ± 0.01	0.25 ± 0.01	0.07 ± 0.0
12.	8 months	0.88 ± 0.01	0.51 ± 0.01	0.20 ± 0.004	0.06 ± 0.0	0.86 ± 0.01	0.40 ± 0.01	0.18 ± 0.01	0.05 ± 0.0
13.	9 months	0.72 ± 0.004	0.45 ± 0.01	0.14 ± 0.004	0.04 ± 0.004	0.69 ± 0.01	0.18 ± 0.004	0.10 ± 0.004	0.03 ± 0.0
14.	10 months	0.51 ± 0.004	0.32 ± 0.004	0.10 ± 0.004	0.02 ± 0.0	0.49 ± 0.01	0.12 ± 0.004	0.05 ± 0.004	0.01 ± 0.0
15.	11 months	0.36 ± 0.0	0.22 ± 0.004	Traces	NIL	0.37 ± 0.004	0.07 ± 0.004	Traces	NIL
16.	12 months	0.19 ± 0.0	0.08 ± 0.01	NIL	NIL	0.19 ± 0.004	0.02 ± 0.004	NIL	NIL

* Room Temperature

FIG.1 Percentage of pesticide residues in treated wheat after one year's storage under different conditions.



DETERMINATION OF PHOSPHINE DOSAGE FOR THE CONTROL OF RESISTANT STORED GRAIN INSECT PESTS IN PAKISTAN

By

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INTRODUCTION

Phosphine fumigation was introduced in the 1960's in the developing countries and it initiated almost a revolution in the approach to fumigation (Friendship et al. 1986). Unfortunately, the wide use of phosphine for fumigation was not accompanied by appropriate training and research to monitor possible consequences of its use on insects. This is perhaps the main cause of the development of resistance to phosphine against stored grain insect pests.

Phosphine resistance was first observed 30 years ago as cross-resistance following selection of Sitophilus granarious (L.) with methyl bromide (Monro et al. 1961). Although the FAO survey in 1973 detected phosphine resistance in 10% of the total number of strains tested from six of the eight species surveyed (Champ and Dyte 1976), there were at that time, no substantiated reports of control failure due to phosphine resistance. Borah and Chahal (1979) were the first to report the failure of phosphine fumigant against the Khapra beetle (Trogoderma granarium) in a warehouse in India. Monitoring of the whole-godown phosphine fumigation in Bangladesh revealed that repeated treatments at a dose rate of 1 g/m^3 in leaky structures resulted in survival of adult insects (Tyler et al. 1983). Strains surviving field fumigation in Bangladesh were tested as adults by Mills (1983) and a high level of resistance was found. Resistance has also been demonstrated in eggs of Rhizopertha dominica (Bell et al. 1977), immature stages of Trogoderma granarium (Borah and Chahal 1979), and in the immature stages of Tribolium castaneum (Saxena and Bhatia 1980).

In Pakistan, the problem of resistance in stored grain insect pest against phosphine was first reported by Taylor (1986) and Taylor and Halliday (1986) in Rhizopertha dominica and Tribolium castaneum. Friendship et al. (1986) had related this development of resistance to the improper fumigation practices in Pakistan.

Winks (1986) proposed three possible strategies for the control of phosphine resistant strains. These are: (1) Fumigation with methyl bromide, (2) Phosphine fumigation with continuous input of a low concentration for the required time, and (3) Phosphine fumigation with optimum dosage.

Methyl bromide is not a real alternative to phosphine because of the residue problems, high cost, and requirements of highly skilled manpower for its application. Application of continuous low phosphine concentration also needs high technology inputs which are not yet available in developing countries. The concept of "optimum dosage" for phosphine fumigation required some experimental work in the context of Pakistan situation. Ahmed et al. (1987) considered that a phosphine concentration of at least 200 ppm (0.28 mg/l) is essential to be maintained for at least seven days in a sealed enclosure for achieving complete control of stored grain insect pest in Pakistan. The later work of Ahmed et al. (1991) revealed that exposure period of even seven days is insufficient for this purpose.

The main objective of the present study is, therefore, to determine "optimal dosage" for phosphine fumigation to control all developmental stages of all species and forms (resistant and susceptible) of stored grain insect pests in Pakistan. This is also essential to arrest the further spread of resistance in

the country.

The work was started in November 1990, on a modest scale and the results available so far are presented here.

MATERIALS AND METHODS

Insects for these experiments were collected from godowns of the Punjab Food Department and PASSCO from Bahawalpur, Hasilpur, Jhalarian, Dunyapur, Manga, and Sehala in first phase (November, 1990) and from Badami Bagh (Lahore), Gujranwala, Sialkot, Gujrat, Jhelum, Rawalpindi, Islamabad-1, Islamabad-2, Attock, Sargodha, Mianwali, Jhang, Faisalabad, and Murdekey in second phase (March, 1991). These insects were kept in the controlled temperature of 30 $\pm 2^{o}C$ and 65 $\pm 5\%$ relative humidity. However, Sitophilus oryzae were kept separately at $25 \pm 2^{o}C$ temperature and $75 \pm 2\%$ relative humidity due to its peculiar breeding requirements. For fumigation chambers, plastic drums of about 60 litres capacity were purchased from local market, out of which 14 drums having uniform rate of leakage of gas were selected. Average leakage rate of phosphine gas in all the selected fumigation chambers were 17 ppm (0.02 mg/l) in 24 hours (Fig.1). Each drum was provided with a nylon capillary tubing for monitoring the gas concentration. Thirty five ml of phosphine gas was introduced in each drum through a puncture in the lid which was then immediately closed with PVC tape after the injection of gas. Phosphine gas was produced in the laboratory using FAO method No. 16 (Anon. 1975). For monitoring phosphine concentration, a "Cititox" phosphine detecting meter (Harris and Cox 1990) was used.

After acclimatizing the field collected insects, mixed cultures from each locality were added separately into about nine kg of clean and de-infested wheat. Insects were then mixed thoroughly with wheat and divided with Boerner's divider into 14 portions of 600-750 gm each. Each of these portions was kept in clean glass jars covered with cloth of fine mesh to restrict insects in the jars. For each experiment, 14 drums (fumigation chambers) were used. Each drum had one or more glass jars containing insects of one locality in a jar. The drums were then transferred to a controlled temperature environment for conditioning of their inner atmosphere before commencing tests. The lids were closed after a few hours. Starting from the third day after the introduction of gas, one drum was opened daily up to 14 days and glass jars containing samples were taken out of them. Two drums were treated as control without gas. One of them was opened after three days and the second at the end of the experiment (14 days).

Insects, alive and dead, present in the fumigated jars were separated, identified for their species and life stages, and counted to assess the mortality of each species at that particular exposure time. Live insects were returned to the same glass jar and incubated for five weeks. The insects were again separated, identified, and counted for live and dead insects.

RESULTS AND DISCUSSION

Low levels of phosphine concentration maintained for longer periods is now recognized as comparatively more effective for the same ct product than high concentrations held briefly (Winks 1984). Furthermore, some developmental stages of insects are known to be very tolerant to high phosphine concentrations held for short periods (Hole et al. 1976, Vincent and Lindgren 1972). Therefore, there has been a continuing trend of lowering concentration of phosphine while extending the minimum exposure period to control resistant insects. Bonds et al. (1977) determined an exposure of 28 days for a concentration of 0.007 g/m^3 of phosphine gas at 25°C to obtain 95% mortality in adults of Sitophilus oryzae. Winks (1984) determined LD_{95} to be 0.002 g/m^3 in adults of Tribolium castaneum for the same exposure period of 28 days at the same temperature. Banks and Ripp (1984) summarized that phosphine fumigation of 0.03 g/m^3 over an exposure period of at least 28 days in well sealed storage is effective for hot and dry grain in West Australia. Considering the situation of Pakistan, Ahmed et al. (1987) postulated that a minimum concentration of 0.28 g/m^3 (200 ppm) may be effective if maintained in all parts of the fumigated space for at least seven days and the enclosure is kept sealed for at least 15 days to take advantage of the tailing down of this concentration. This was, however, yet to be verified through laboratory experiments. Hence, the main objective of the present study was to determine the minimum essential exposure period for phosphine fumigation of insects to obtain complete mortality in a mixed population of stored insect pests.

Results presented in Table 1 show that for complete mortality of mixed population, a concentration of above 240 ppm (0.33 mg/l) was required for an exposure period at least of 14 days. The results also showed that maximum resistance to phosphine has developed in Trogoderma granarium collected from Dunyapur and Tribolium castaneum collected from godown No.4 at Manga. Resistance to phosphine was also observed in the strains of Trogoderma granarium collected from godowns No. 9 and 4 at Manga, Jhalarian, Hasilpur, Faisalabad, and Bahawalpur, while those collected from Murdekey, Badami Bagh, Rawalpindi, Sargodha, and Quaidabad showed moderate level (all insects were killed in five to six days of exposure) and those from Islamabad, Jhang, Jhelum, and Sehala were found to have no resistance (all the insects were killed in three to four days after fumigation). High levels of resistance to phosphine were also observed in some strains of Tribolium castaneum (Table 1). The strain from Manga (4) was the most resistant and required 14 days exposure period to achieve complete mortality. Resistance was also observed in strains of this species collected from Hasilpur, Manga (9), and Dunyapur. The other strains were found to be less resistant. The most tolerant strains of Rhizopertha dominica were collected from Hasilpur which required 11 days for complete kill. Specimens of this species obtained from Manga (4) showed a moderate level of tolerance (complete mortality was attained after five days of fumigation). All other strains of this species and other species collected from various localities did not exhibit unusual tolerance. Tribolium castaneum collected from two different godowns of Manga storage complex showed different levels of tolerance. Insects collected from godown No. 9 needed seven days of exposure, while those collected from godown No. 4 required 14 days for complete mortality (Table 1). Results of Table 2.1 and 2.2 revealed that in most cases 90% of the insect population was killed in the

first six to eight days of fumigation, while the remaining 10% required a much longer exposure period. It means that the majority of insects in the population did not exhibit high levels of tolerance and were killed in the first six to eight days. The remaining insects, however, proved to have high resistance (Figure 1).

Hole et al. (1976) quoted a mean concentration of 0.32 mg/l for seven days exposure for the control of pupae of Sitophilus oryzae. Mills (1986) observed the survival of adults of Rhizopertha dominica and Cryptolestes ferrugenius at the same dosage. In the present studies, it was observed that the larvae of Trogoderma granarium, (Dunyapur), survived the concentration of above 0.33 mg/l exposed for 13 days (complete mortality was obtained after 14 days) (Table 3). In another strain (Manga 9) of the same species, the larvae and pupae survived the same concentration for 11 days. The larvae of Tribolium castaneum, (Manga 4) also survived this concentration for 13 days. The most tolerant stage of Rhizopertha dominica was the adult collected from Hasilpur which survived for ten days and complete mortality was achieved in 11 days.

The suggestion given by Winks (1980) that at temperatures of 25°C and above, a ct product of 150 mg/l/h for a period of at least seven days controls all species is not applicable for many strains of stored grain insect pests in Pakistan. Some strains of Trogoderma granarium and Tribolium castaneum were killed at a ct product of 168.1 mg/l/h with an exposure period of 14 days at temperatures of 25°C. In the case of Rhizopertha dominica, the most tolerant strain (Hasilpur) was completely killed at a ct product of 141.1 mg/l/h in 11 days (Table 4). The susceptible strains of these species were killed at a ct product of 46.1 mg/l/h in three days and/or 61.1 mg/l/h in four days.

In view of the results obtained so far, it is concluded that the phosphine concentration of above or equal to 0.33 mg/l (240 ppm) for an exposure period of at least 14 days is required to kill all life stages and resistant forms of stored grain insect pests present in Pakistan.

ACKNOWLEDGEMENTS

The authors are highly grateful to Dr. Hafiz Ahmed (Consultant, STDT Project), Dr. R. C. Maxon (Chief of party, STDT Project) and Dr. U. A. Acasio (Long term advisor, STDT Project) for their valuable suggestions and continued interest throughout this study. This work was financially supported by the STDT/FSM Project. Their support is also acknowledged.

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TABLE 1

Exposure Period (days) Required for Achieving Complete Kill in Various Species of Stored Grain Insect Pests Collected from Different Localities.

No.	Localities	T.g.*	R.d.*	T.c.*	S.o.*	C.f.*
1	Bahawalpur	7	-	-	-	-
2	Jhalarian	11	-	-	-	-
3	Hasilpur	9	11	12	-	-
4	Dunyapur	14	-	6	-	-
5	Manga (4)	11	5	14	-	3
6	Manga (9)	12	3	7	-	-
7	Badami Bagh	5	-	-	-	-
8	Murdekey	6	3	3	3	-
9	Islamabad-1	4	4	3	-	-
10	Islamabad-2	3	3	3	-	-
11	Sehala	3	-	-	-	-
12	Jhelum	3	3	3	-	-
13	Rawalpindi	6	3	3	-	-
14	Sargodha	5	3	3	-	-
15	Quaidabad	5	4	3	-	-
16	Jhang	3	3	3	-	-
17	Faisalabad	8	3	3	-	-

*

T.g. - *Trogoderma granarium*
R.d. - *Rhizopertha dominica*
T.c. - *Tribolium castaneum*
S.o. - *Sitophilus oryzae*
C.f. - *Cryptolestes ferrugenius*

TABLE 2.1

Exposure to periods and percent mortality in different strains of Trogoderma granarium phosphine concentration above 240 ppm (0.33 mg/l)

Localities	Exposure period (days)											
	3	4	5	6	7	8	9	10	11	12	13	14
Bahawalpur	98	99.4	99.2	99.4	100							
Jhalarian	27	66	88	92	99	99.8	99.8	99.9	100			
Hasilpur	28	78	93	97	99.5	99.9	100					
Duryapur	29	54	64	91	95	97	98	99.5	99.7	99.8	99.9	100
Manga (4)	89	78	82	88	97	99	99.9	99.9	100			
Manga (9)	13	21	43	66	76	92	95	93	95	100		
Murdekey	70	80	98	100								
Rawalpindi	88	95	99	100								
Faisalabad	60	72	87	95	99	100						

TABLE 2.2

Exposure periods and percent mortality in different strains of *Tribolium castaneum* and *Rhizopertha dominica* at phosphine concentrations above 240 ppm

Tribolium castaneum												
Localities	Exposure period (days)											
	3	4	5	6	7	8	9	10	11	12	13	14
Hasilpur	50	61	73	92	95	98	99	99	99.5	100		
Dunyapur	60	64	81	100								
Manga (4)	35	70	94	94	94	94	95	95	96	96	96.5	100
Manga (9)	42	50	60	75	100							
Rhizopertha dominica												
Hasilpur	52	78	83	91	95	97	98.5	99.5	100			
Manga (4)	98	99.5	100									

TABLE 3

Developmental stages of insect strains collected from various localities surviving the maximum exposure period (days) at a phosphine concentration of above 240 ppm (0.33 mg/l).

Species	*Trogoderma granarium*		*Tribolium castaneum*		*Rhizopertha dominica*	
Localities	Stages	E.P.*	Stages	E.P.	Stages	E.P.
Bahawalpur	pupae	6	Nil	Nil	Nil	Nil
Jhalarian	Larvae	10	Nil	Nil	Nil	Nil
Hasilpur	Larvae	8	Larvae	11	Adults	10
Dunyapur	Larvae	13	Pupae	5		-
Manga (4)	Larvae	10	Larvae	13	Adults	4
Manga (9)	Larvae Pupae	11	Adults	6	-	-
Faisalabad	Larvae	7	-	-	-	-
Quaidabad	Pupae	4	Nil	Nil	Adults	3
Murdekey	Larvae	5	-	-	-	-
Rawalpindi	Larvae	5	-	-	-	-

* Exposure period (days).

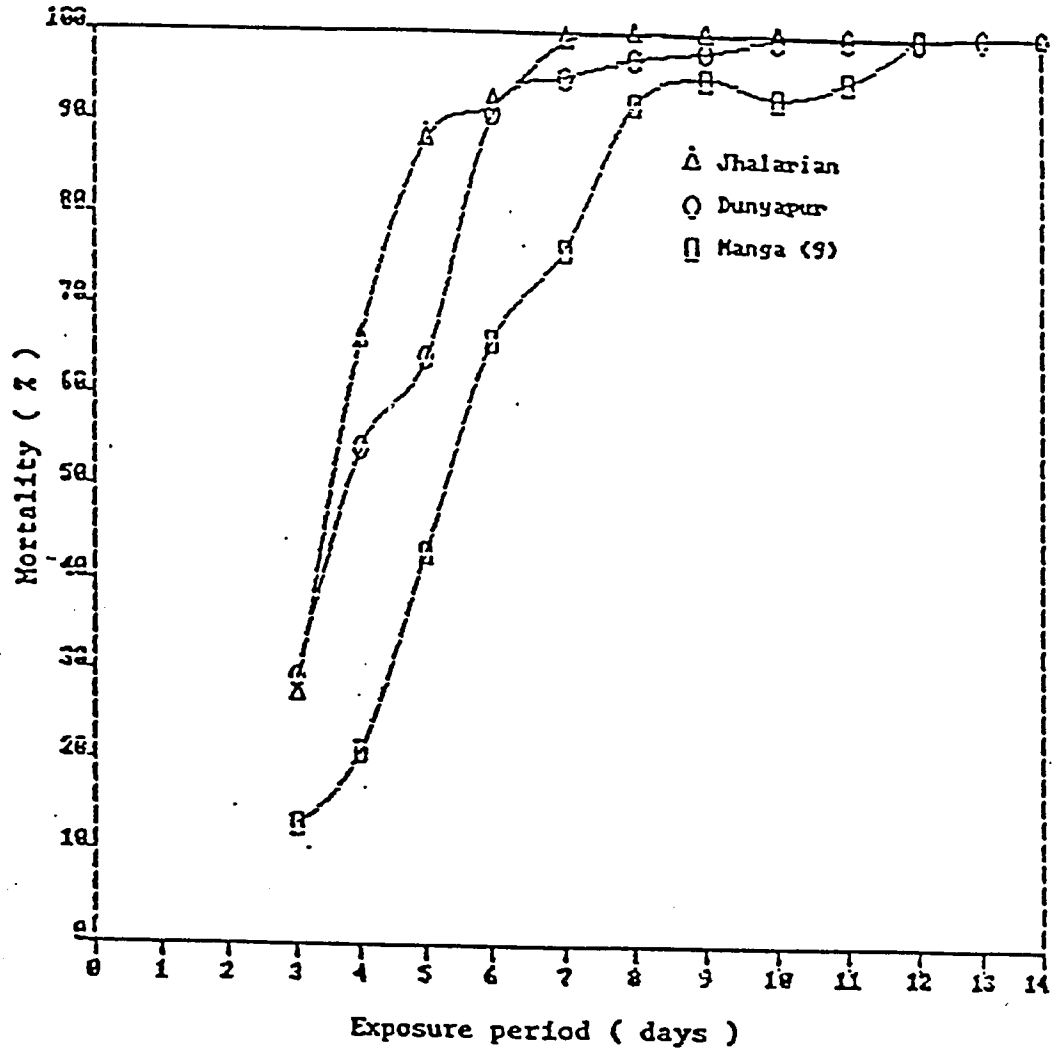

Figure 1 : Mortality results from phosphine fumigation of three strains of Trogoderma granarium at a concentration of above 0.33 mg/l.

BULK WHEAT HANDLING: A PAKISTAN EXPERIENCE[1]

By

Ulysses A. Acasio[2]

ABSTRACT

A pilot project to determine the feasibility of converting Pakistan's bag handling systems to bulk handling was initiated during the 1990 wheat harvest. The Project is ongoing and will conclude after the 1992 wheat harvest season. The research project is to test various combinations of bulk grain handling equipment for procurement, storage, and distribution mainly in the province of the Punjab. A comparison of operational costs and mechanical efficiency of bulk grain handling system compared with existing bag handling systems will be the final output of the exercise. The imported portable grain handling and transport equipment used in the study proved to be applicable with little or no substantial modifications.

Pakistan is under increasing pressure to reform its grain handling systems. Seasonal labor shortages, increasing volumes, rising costs and shorter harvest seasons are contributing factors that call for a more efficient and reliable system of grain handling and storage. While additional storage capacity is needed, the efficient utilization of existing facilities offers a viable alternative to the construction of new ones.

Initial results of this research project have created interest both in the public and private sector food grain agencies. Even before its completion, the research project has demonstrated a feasible method of handling wheat at procurement up to the mills. The results of the exercise will have substantial impact upon the future direction of wheat handling and storage in Pakistan.

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INTRODUCTION

Pakistan is one of the few countries that produces both wheat and rice using the same fields in the same year. While wheat is the staple food, Pakistan grows an aromatic rice variety (Basmati) mainly as an export crop. Farmers produce a major portion of both crops in irrigated lands with good control of water. Growers drain the fields long before harvest to facilitate the use of machines for harvesting and threshing such as the self-propelled combine. The predominant method of handling both wheat and rice is in bags.

The annual national production of both crops is about 14.5M mt of wheat and 6.5M mt of paddy. About 50 percent of the wheat crop winds up in the open market. The public sector procures about 5M mt or 70% of all wheat in the open market. In the past, the Rice Export Corporation of Pakistan used to procure about 40% of the total milled rice mainly for the international market. Today, the share of the private sector in the export market has significantly increased due to the privatization policy of the government.

In terms of grain storage, the public sector has a capacity of about 4M mt for wheat and 1.2M mt for rice. Of the total public sector storage capacity, only about 200,000 mt are in vertical silo structures. The private sector has less than 200,000 mt of dedicated grain storage facilities due to government policies which absorb over 90% of the storage and distribution costs for wheat.

In the last two decades, many international donor and lending agencies have studied and proposed various plans and strategies to upgrade the existing storage systems in Pakistan. Among the comprehensive ones are those of Canada (Watson Engineers, Inc., 1970 and Carr and Donald, 1980), Denmark (Hoff and Overgaard, 1985), World Bank (World Bank Report 3360-PAK, 1981), Asian Development Bank (ADB Report Ap-48, 1983), and USAID (Borsdorf, et al., 1987 and Experience, Inc., 1988).

Pakistan has six basic types of permanent or fixed grain storage facilities namely: godowns, hexagonal bins, metal silos, concrete silos, dome-shaped structures (Binishell) and bunker-type storage or open bulkheads (Qureshi, 1989). The major grain silos are owned by provincial and federal governments. With the exception of a private sector silo that was nationalized in 1972, all other silos were built in the last 10 years. However, only two silos are useable and in dire need of repair. The remaining silos are non-operational either due to worn out equipment and/or basic flaws in the design of their grain handling systems (Acasio, 1989). For example, the government commissioned a 60,000 mt silo five years ago. It ran partially for one season and then was abandoned due to poorly designed equipment and fundamental structural design errors. (Acasio and Maxon, 1989).

A new silo with a little improvement in design over the last one is nearing completion but again will face the same problems as the previous silos. Its design concept is mainly to convert bag wheat to bulk form and vice versa. Its receiving capacity is a measly 70 mt per hour. A comparable silo installation in other countries would have at least 200 mt per hour.

Aside from the vertical storage facilities, Pakistan has recently constructed

thirty bunker-type storage facilities with a combined capacity of 150,000 mt. The government built these facilities with savings from a World Bank Grain Storage Project that established a national network of covered storage facilities, (World Bank, 1981).

The Pakistan Storage and Services Corporation (PASSCO) built the first bunker-type storage facility in 1986. It uses a portable inclined bucket elevator for loading wheat. However, its conveying capacity was only about 18 mt/hour and its length was not sufficient to reach the center line of the bunker. As a result, PASSCO resorted to manual labor to convert bagged wheat into bulk form and then re-bagged the stored wheat from the bulkhead during the reclaiming operation. This method proved to be inefficient and uneconomical compared with the existing bagged wheat handling and storage system.

Both PASSCO and the Food Departments normally augment their storage capacity by temporarily storing bagged wheat on outdoor platforms. They pile the bags in pyramid-shaped stacks and cover it with tarpaulin or plastic sheets mainly for protection from rain. This is a high risk system of storage because of frequent storms and flooding immediately after harvest. They are also prone to attacks from vertebrate pests. It is also a common practice to store bulk wheat in a godown using bag grain as retaining walls (bag-cum-bulk). The retaining walls are necessary as the godown walls can only sustain lateral pressures of bulk wheat not more than five feet above the floor level. Storage managers build the retaining walls about four feet from the brick wall and pour in bulk wheat in the enclosed space. This method can increase the storage capacity of a godown to 1.5 times its rated bagged grain capacity.

Bulk storage is not new in Pakistan. The first bulk storage facility (hexagonal bins) came into being in Pakistan long before partition. This facility still stands solid in the city of Faisalabad. The Punjab Food Department can put this historic facility to good use again as it has just been rehabilitated under a USAID-funded Project. The British built many more hexagonal bins of a smaller size about 45 years ago. Most of these bins are still in fairly good shape excepting a few which have minor defects. The same USAID project has rehabilitated a number of these bins. However, bulk wheat handling and storage, as is done in more advanced agricultural systems, is still in its infancy in Pakistan. To make bulk handling and storage efficient and economical, it has to be a complete system from the farm to the end user. The STDT Bulk Research Project is attempting to show a complete system of bulk wheat handling under Pakistan conditions.

The bulk wheat handling and storage system has potential for rapid adoption in Pakistan if the Project achieves positive results. I base this assumption on the widespread use of mechanical threshers and the rapid growth in the number of combine harvesters in Pakistan within the past 5 years. This is a major factor, in addition to the rapid rise in the price of jute sacks, that favors the adoption of bulk handling and storage of wheat in Pakistan now.

In addition, the timely pricing incentives can further accelerate the adoption of bulk handling and storage in the private sector. Until 1987, the government absorbed all costs of wheat storage, protection, and distribution. Since that time, the margin between procurement and release price has gradually increased.

Last year"s difference was about 8% and rose to about 15% this year. This year the private sector aggressively procured wheat from the open market causing concern among many purchase officers of the PFDs and PASSCO. This step is in the right direction if Pakistan hopes to achieve self reliance in basic food grains.

Flour millers calculate their storage costs as about 1/2 the government costs, hence many are now contemplating to construct their own storage facilities. Some progressive millers are now considering "convertible godowns" capable of storing either bag or bulk wheat and finished products. A leading flour miller in Islamabad is now installing a bulk handling system in its convertible godown. Aside from being able to receive wheat either in bag or bulk, the owner will be able to convey bulk wheat from the godown directly to his flour mill. Competitive pressures and rising costs will force other mills to take a serious look at this alternative system of wheat handling and storage.

STATEMENT OF THE PROBLEM

1. Increasing volumes of grain requires rapid handling in progressively shorter time periods. The harvest season both for wheat and paddy rice has shrunk from two to three months to less than four weeks. The PASSCO and Food Departments must moved the wheat quickly to covered storage to avoid possible losses due to rain and vertebrate pests. The monsoon season begins shortly after (sometimes during) harvest.

2. Wheat grain comes in bulk form after threshing, then it goes through bagging, emptying, and re-bagging operations up to four times during procurement, storage, and distribution. Producers deliver wheat to middlemen in bags and then transform into bulk by dumping it on the ground. This is mainly to standardize the weight and quality of the grain and partly due to the shortage of jute sacks. The bulk system should start at this point in the grain chain to avoid the cost of the sack. At silo installations, laborers manually pour wheat from the bag into the receiving pit of the bucket elevator. In hexagonal bin installations, laborers carry 100Kg bags up 52 steps to the top of bins and empty them individually into a hatch. Similarly, laborers fill bag-cum-bulk and bunker-type storage manually for lack of appropriate mechanical grain handling equipment. They also re-bag the wheat for delivery to the flour mills or end users.

3. Grain storage and handling costs are increasing at a rate greater than rises in the general price level. In spite of wheat subsidies which have doubled since 1987, flour millers and growers pass on to consumers the additional costs of producing flour. Rural-to-urban migration has created chronic shortages of labor for bag handling during harvest. The shorter turn around times between wheat and follow-on crops require rapid clearing of the fields. This competes with available farm labor, thus contributing to labor shortage. The cost of jute sack has risen from Rs. 12 in 1988 to Rs 27.25 today.

4. Increased resistance to phosphine gas by stored grain insects. This problem arose from under-dosage practice and insufficient exposure time because of gas leakages in the warehouses (Maxon, 1989 and Halliday, 1989). An alternative method of protecting the grain will have to be developed. This is one area where research and development efforts in the region will have to focus on (Banks, 1987) as the techniques in use today in pest control were developed 40-50 years ago.

5. Inadequate grades and standards plus obsolete operating policies create anomalies in storage. It is common knowledge that wheat stocks both in the private and public sectors contain excessive foreign materials. The No Loss Policy in the public sector prevents adoption of improved storage practices such as cleaning wheat before storage. Enforcement of the Fair Average Quality (FAQ) grain grades and standards remains elusive. The British established FAQ before independence and does not contain standard procedures to objectively determine grain quality (Maxon, et al. 1988). STDT has sufficient data from surveys it conducted in wheat surplus areas

in 1988, 1989, and 1990 to serve as a basis in developing a new grain grades and standards for Pakistan.

RATIONALE

The public and private sectors of Pakistan are increasingly under pressure to cope with the above situations. While a bag system may be adequate for limited volumes of grain, it does not lend itself to economies of scale. It is vulnerable to chronic shortages of labor, vagaries of nature, and dependence on imported jute sacks. While permanent structures are more expensive to build, one can always rely on them regardless of the political and economic climate in the country or what foreign experts say against them. Modern grain handling and storage systems offer a viable alternative to the traditional bag handling system. Life is replete with examples that the cheapest is not necessarily the best. Otherwise, we should all be riding bicycles as this is cheaper than using a car or flying in an airplane to get where we want to go. Timeliness and a better way of life are two important factors that are hard to put value on.

In contrast, bulk handling and storage of grains in western economies did not occur overnight, but arose to meet increasing volumes and competition for labor and capital resources. The same factors are now appearing in Pakistan with a similar trend and intensity. Hence, bulk grain system for Pakistan is an idea whose time may have finally come after many false starts.

The Bulk Research Project was initiated by the USAID Mission to Pakistan through the Storage Technology Development Transfer (STDT) component of its Food Security Management Project (FFGI Proposal, 1988). Initially, this project was a joint undertaking of the (FFGI of Kansas State University (KSU) and (PASSCO). PASSCO is a parastatal agency responsible for procuring and transferring wheat from surplus growing areas to the deficit areas of Pakistan. Lately, the Provincial Food Departments (PFDs), which maintain wheat reserves within the provinces, have collaborated in the delivery of bulk wheat from their stocks to selected flour mills in Multan, Okara, and Lahore. They have also cooperated with STDT in filling their hexagonal bins in Sahiwal and Okara to gather operational and economic data.

OBJECTIVES OF THE PROJECT

1. To design a complete bulk wheat handling system from the producer to storage to end users (flour mills).

2. To test and modify the system to make it practical, efficient, and replicable under similar conditions.

3. To promote local capability in the operation, maintenance, repair, and fabrication of the various equipment used in each component of the whole system.

4. To analyze each component of the system for cost effectiveness, social impact, and management problems.

METHODOLOGY

The essence of the Bulk Research Project is the use of mechanical systems of lifting, transporting, weighing, conveying, storing, and dispatch of wheat in bulk form. To achieve the above objectives, STDT initially selected the PASSCO facilities at Depalpur in the Punjab and its supply area for the collection and storage phase of the pilot project (Phase I).

STDT and USAID imported several portable grain handling and transport equipment from the USA. STDT and PASSCO technicians assembled and tested practically all the imported portable equipment used in the project with the guidance of the author prior to the 1990 wheat season. Only a few pieces of equipment required any modifications. A major innovation in the project is the mobile grain pump which is tractor-mounted and PTO driven for greater mobility.

Table 1 describes the various bulk handling and transport equipment used in the study during the 1990 and 1991 wheat procurement seasons.

The flow diagram in Figure 1 shows the movement of grain around Depalpur during the procurement season. Figure 2 shows how STDT and PASSCO personnel collected wheat from a local grain market. Meanwhile, Figures 3 and 4 show graphically the collection, transport, and storage of the wheat, respectively.

STDT and PASSCO initiated the collecting and storing of bulk wheat in the 1990 wheat procurement season. The involvement of the Punjab Food Department in the STDT Research Project has expanded since last December. This year, they have allowed STDT to fill their hexagonal bins in Sahiwal and Okara. The cycle of collecting, storing, and delivery will be concluded in the wheat procurement season of 1992. STDT will collect relevant operational and economic data that will shed light on the merits of bulk wheat handling under Pakistan conditions. Dr. Richard C. Maxon, Chief of Party of STDT will discuss initial results of the bulk handling trials during the 1990 and 1991 procurement seasons. STDT should be able to complete in August 1992 the economic and operational evaluation of the entire three-year bulk handling and storage research project.

The reclaiming and dispatching operations (Phase II) of the pilot project will commence in the last quarter of 1991. The Project will dispatch wheat from Depalpur to Peshawar using self-tipping bulk trucks and hopper-bottomed trailers acquired under the World Bank and STDT/FSM projects, respectively. At Depalpur, the reclaiming of bulk wheat from the open bulkheads will require the use of a flat storage unloader (Figure 5). The Project will use the hopper-bottomed bulk trailer shown in Figure 6 to deliver bulk wheat to storage facilities or flour millers with bulk receiving and storage systems.

In December 1990, STDT conducted initial trials in the delivery of bulk wheat from the PFD silos in Multan to selected flour mills in the area. Early this year, STDT also delivered bulk wheat from the PFD hexagonal bins in Okara and Lahore to selected local flour mills. At Badami Bagh in Lahore, STDT reclaimed wheat from the hexagonal bins with the use of a portable auger, portable inclined grain pump, and self-tipping bulk truck. The bulk truck delivered the wheat to a flour miller within the city of Lahore. (Figure 7). Figure 8 shows the

reclaiming of wheat from the hexagonal bins of the PFD.

In addition to grain handling, STDT has collaborated with the former Pest Management and Research Institute (PMRI) in Karachi in experimenting with several methods of protecting wheat from insect pests both in bag and bulk forms. Previous speakers have already presented the results of the major studies conducted in the STDT Project.

PRELIMINARY RESULTS AND OBSERVATIONS

In the 1990 wheat season, the Bulk Project collected and stored a total of 10,190 mt of wheat in three bulkheads at the pilot storage and collection center in Depalpur. Of the total wheat stored, STDT collected about 20% completely in bulk form from local grain markets (commission agents) and from large farm owners. The gravity wagons hauled most of the bulk wheat within a radius of five km while an eight-ton bulk truck brought in wheat from sources between five and 15 km. Project personnel weighed bulk wheat on a weighbridge while laborers randomly weighed bag wheat on a portable platform scale. Because of the "No Loss Policy" of the government of Pakistan, PASSCO did not allow STDT to clean the wheat before it went into storage.

This year, STDT, PASSCO and the Punjab Food Department agreed to repeat the exercise with major emphasis on bulk wheat, although the exercise did not preclude the conversion of bag wheat to bulk form. The sites selected for PASSCO were Depalpur and Chichawatni while Sahiwal and Okara were selected for the Punjab Food Department. PASSCO assigned a number of silos at Chichawatni for the exercise. A USAID-funded Project is currently renovating the entire Chichawatni silo complex.

Because of the aggressive participation of the private sector in the 1991 wheat procurement season, STDT collected only about 800 mt of bulk wheat from the open market at Depalpur. The same factor limited the collection of bulk wheat in Chichawatni to only 135 mt, 65 mt in Sahiwal, and nothing in Okara. At Sahiwal and Okara, STDT and PFD decided to fill the hexagonal bins with converted bulk wheat using bulk handling equipment (Figure 9).

With the initial success and experience in the introduction of bulk wheat handling in Pakistan, we can make the following observations:

1. There is a need to clean the grain at the point of entry to the bulk chain to minimize wear and tear on grain conveyors.
   Grain protectants can be admixed more effectively with clean grain than dirty grain.

2. Initial resistance offered by field personnel of the PASSCO and commission agents (middlemen) was effectively overcome by demonstration of the benefits to them and indirect pressure from grain producers and merchants. This confirms the assertion of Lindner (Lindner, 1986) that the primary consideration in the adoption of a new technology is its appropriateness to the potential adopter or user. The farmers and middlemen readily recognized the potential savings they can make by adopting bulk handling of wheat.

3. The imported bulk handling equipment is suitable for local use and manufacture. They require little modification or adaptation to suit local conditions. A few examples of equipment adaptations are: use of caster wheels on grain pumps, surge hoppers to feed the grain, and a mobile grain pump (Figure 10) to pick up grain from a grain pile.

4. The imported gravity wagon (Figure 11) with a capacity of 5.5 mt is more suitable for short rather than long hauls which is more appropriate with a self-tipping bulk truck. Some farmers brought in their wheat using a locally made trolley shown in Figure 12. A local manufacturer is now making a self-tipping trolley based on STDT specifications with at least a capacity of about 8 mt.

5. A series of bucket spouts can spread wheat over a wider area in the bulkhead without moving the drag conveyor. Figure 13 shows how the gadget works, while Figure 14 shows a completely covered open bulkhead storage structure.

6. One can spray a grain protectant effectively to the wheat stream as it flows from the discharge spout of a gravity wagon to the feed hopper of a grain pump. The feed auger does most of the mixing process. Further mixing occurs as the grain goes through the grain pump.

7. Local entrepreneurs are capable of making suitable bulk grain handling equipment if given proper technical guidance. As an example, a local manufacturer successfully cloned one of the grain pumps in the project. The modification of a 35 ft grain pump to a self-propelled and powered unit was made possible with local craftsmanship and resources.

FUTURE ACTIVITIES

1. Repeat the collection, storage, and delivery of bulk wheat in the selected areas in the Pakistan.

2. Reclaim grain from bulk storage facilities (silos, bunker, bag-cum-bulk, and hexagonal bins) and deliver it to millers within the same surplus area and to a deficit province.

3. Analyze the bulk handling and storage data and compare the operating cost with a comparable scale of bag handling and storage system.

4. Fill and reclaim wheat from a convertible godown of PASSCO using portable grain conveyors.

5. Operate the renovated silos in Chichawatni and Multan and develop a management guide for PASSCO and PFD personnel.

CONCLUSIONS

Based on the two-year experience of STDT in bulk wheat handling in Pakistan, we can conclude that bulk handling in Pakistan is now feasible technically and operationally. This is a consequence of the rapid adoption of mechanized threshing and combining. Bulk wheat is now available for collection at the farm level and at local grain markets.

The bulk wheat handling and transport equipment used in the exercise are suitable for local use. Local fabrication of the various equipment is economically and technically feasible.

While the cost data of bulk handling and storage is still incomplete, the timeliness and reduction in the dependence of unreliable labor supply and jute sacks were important factors that became evident in the entire exercise.

The enthusiasm and readiness by producers and middlemen in embracing bulk wheat was the most pleasant and unanticipated surprises of the whole exercise. The potential economic benefits for bulk wheat handling and storage has finally caught the attention of the normally conservative upper level officials in the Food Departments, PASSCO, and the Government of Pakistan. Their expressed desire at a recent meeting is to gradually increase wheat procured in bulk in next year's wheat procurement season. STDT strongly believes that bulk handling and storage is an idea whose time has finally come to Pakistan.

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Table 1
LIST OF BULK HANDLING EQUIPMENT USED IN THE PROJECT

Item No.	Equipment	Description	Quantity	Capacity
1.	Grain pump	Chain conveyor, 10.7 m long, 15 cm dia. UHMW plastic paddles, 5.6 kw motor.	9	55 mt/hr
2.	Mass-ter Mover 50	Chain conveyor, 14 x 22 cm UHMW plastic paddles, PTO drive, 24.5 m long.	1	135 mt/hr
3.	Mass-ter Mover 50	Chain conveyor, 14 x 22 cm UHMW plastic paddles, 20 m long, 11.25 kw, 3 phase motor,	1	135 mt/hr
4.	Truck Unloader	Chain conveyor, 9 x 32 cm UHMW plastic paddles, 5.6 kw, 3 phase motor, with wheels.	3	135 mt/hr
5.	Truck Unloader	Screw conveyor, 20.3 cm dia. flight, 3.75 kw, 3 phase motor, equipped with wheels.	6	60 mt/hr
6.	Portable Grain cleaner	Rotating outer screen and an inner cone-shaped screen for to separate large foreign materials, 1.5 kw main drive and 2.25 kw feed auger motors.	4	60 mt/hr
7.	Gravity Wagon	Hopper bottomed, two axle, four wheel, side discharge.	8	5.5 mt
8.	Flat Storage Unloader	Chain conveyor, tractor mounted, PTO driven, 15.25 m long, hydraulic lift, hydraulic swivelled spout. 17 x 32 cm UHMW plastic paddles.	2	270 mt/hr
9.	Portable Augers	Snap-on type portable auger, 20.3 cm dia. flight, with inlet hopper, 5.6 kw, 3 phase motor.	6	60 mt/hr
10.	Portable Generator	220/440 VAC, two-wheeled, diesel powered, water cooled.	5	35 KVA
11.	Portable grain pump	65 ft, 6" diameter paddles, PTO driven, drag chain.	2	35 mt/Hr
12.	Mobile grain pump	35 ft, 6" diameter paddles, tractor mounted, PTO driven	1	35 mt/Hr

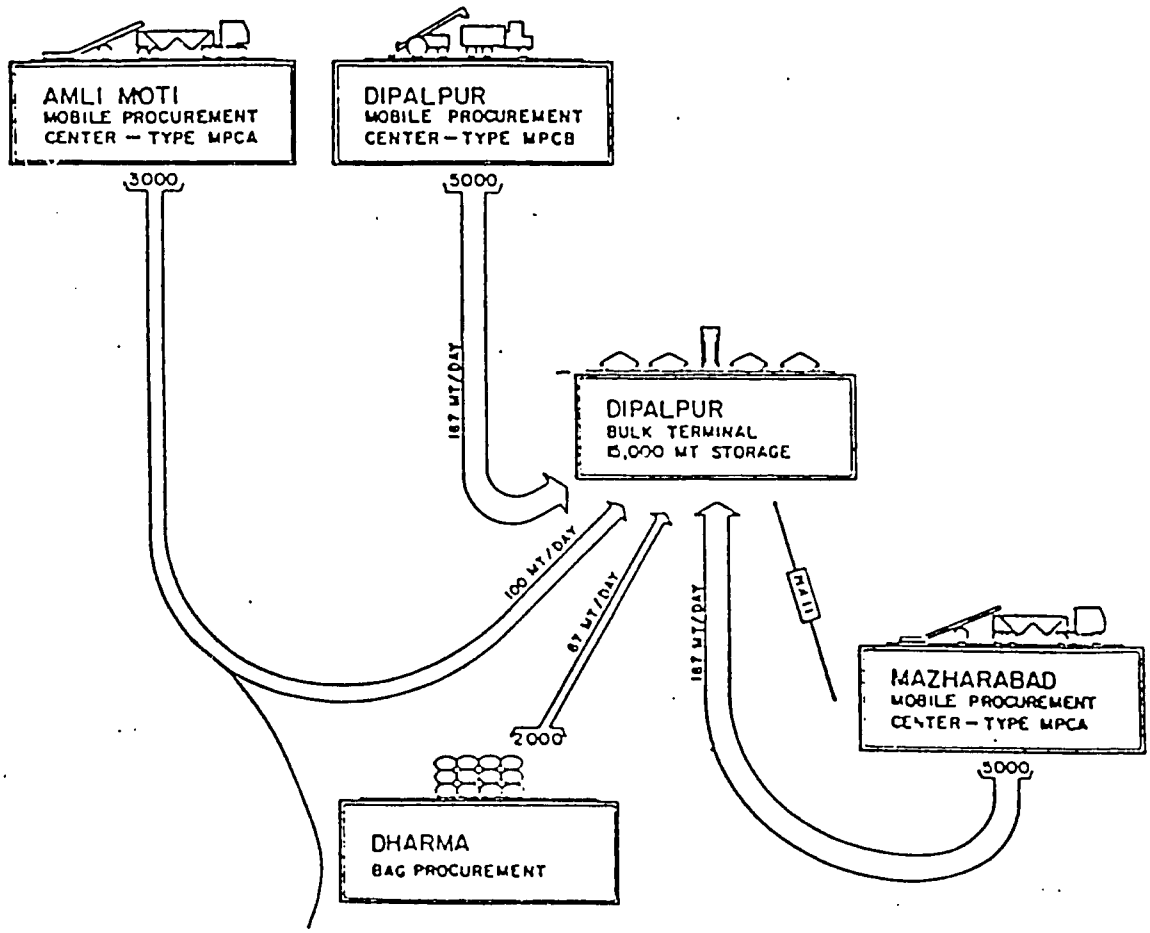

Figure 1. Diagram showing the movement of grain from the purchase centers and local grain markets in the pilot project.

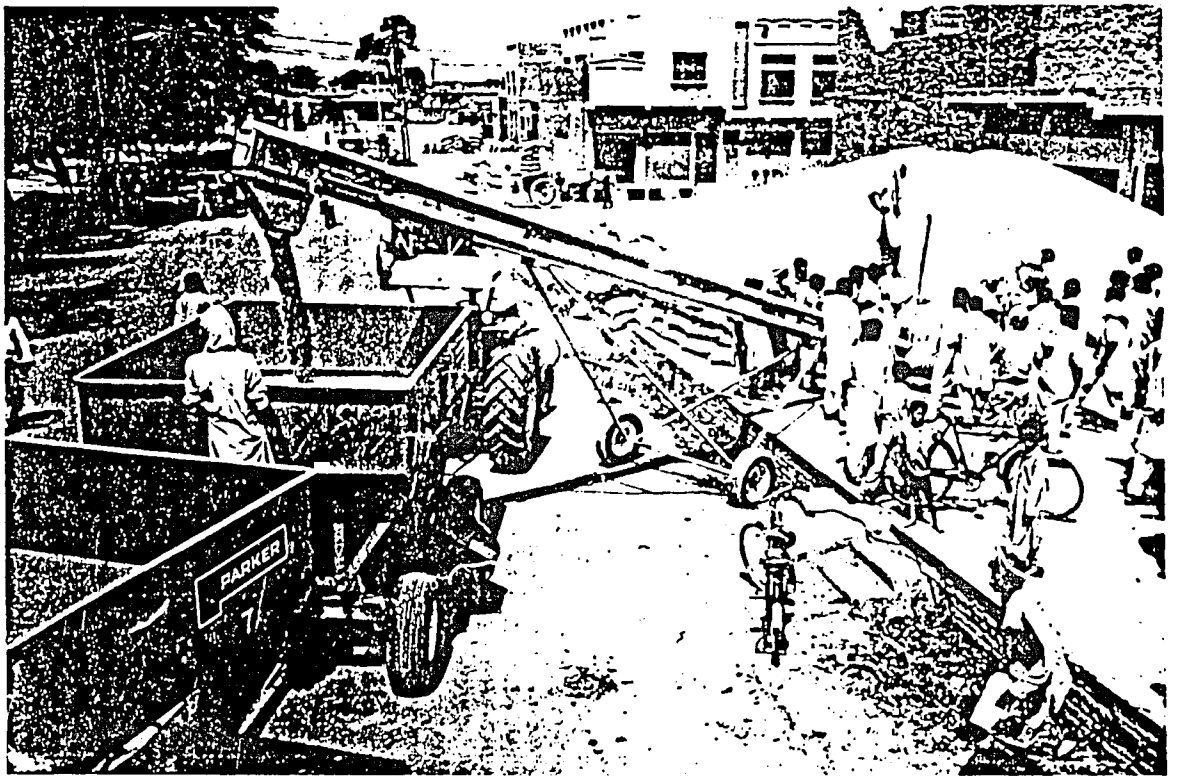

Figure 2. Collecting grain from a local market with the gravity wagons and a portable chain conveyor (grain pump).

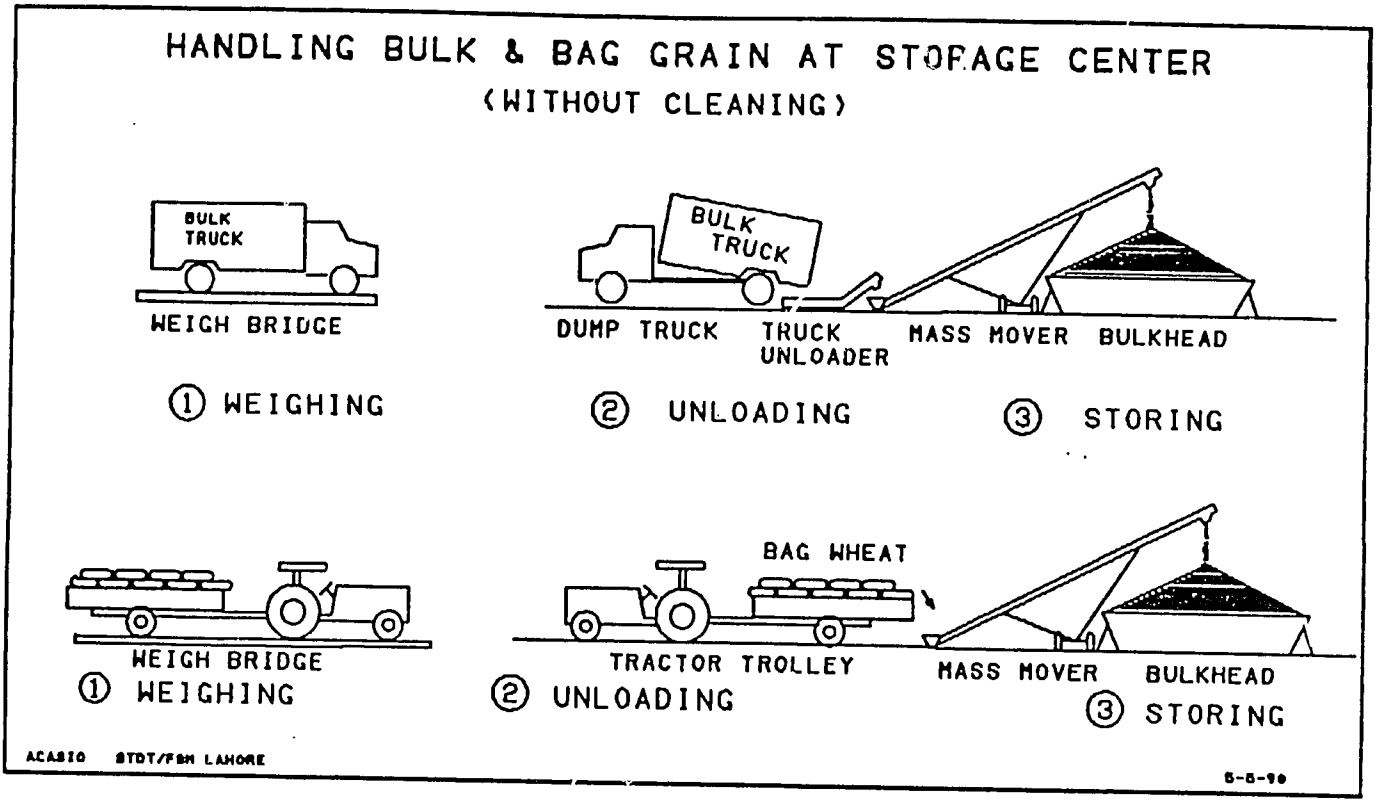

Figure 3. Schematic diagram of bulk and bag handling of wheat at the pilot open bulkhead storage center.

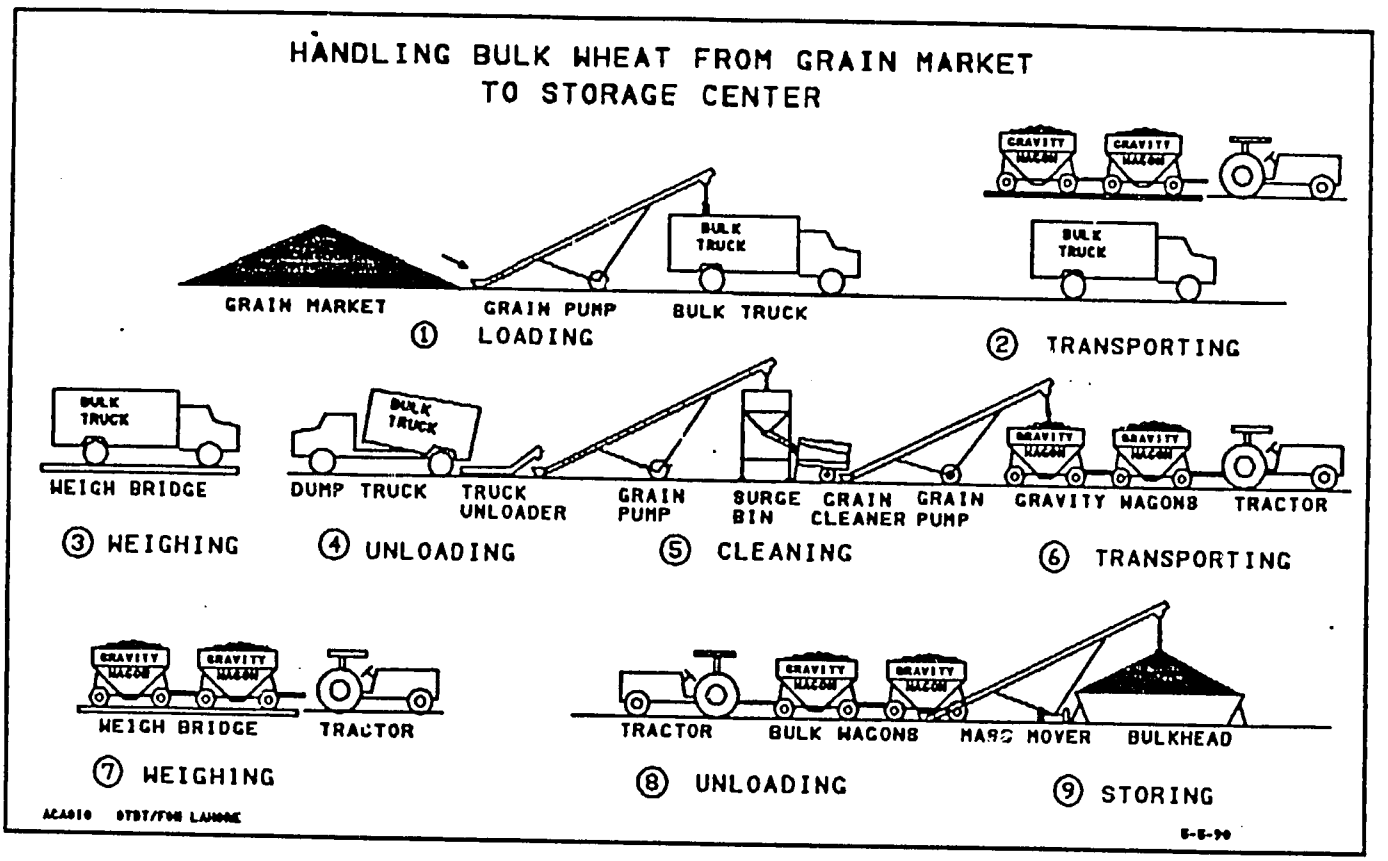

Figure 4. Schematic diagram of collecting and transporting bulk wheat from a local grain market to the storage center.

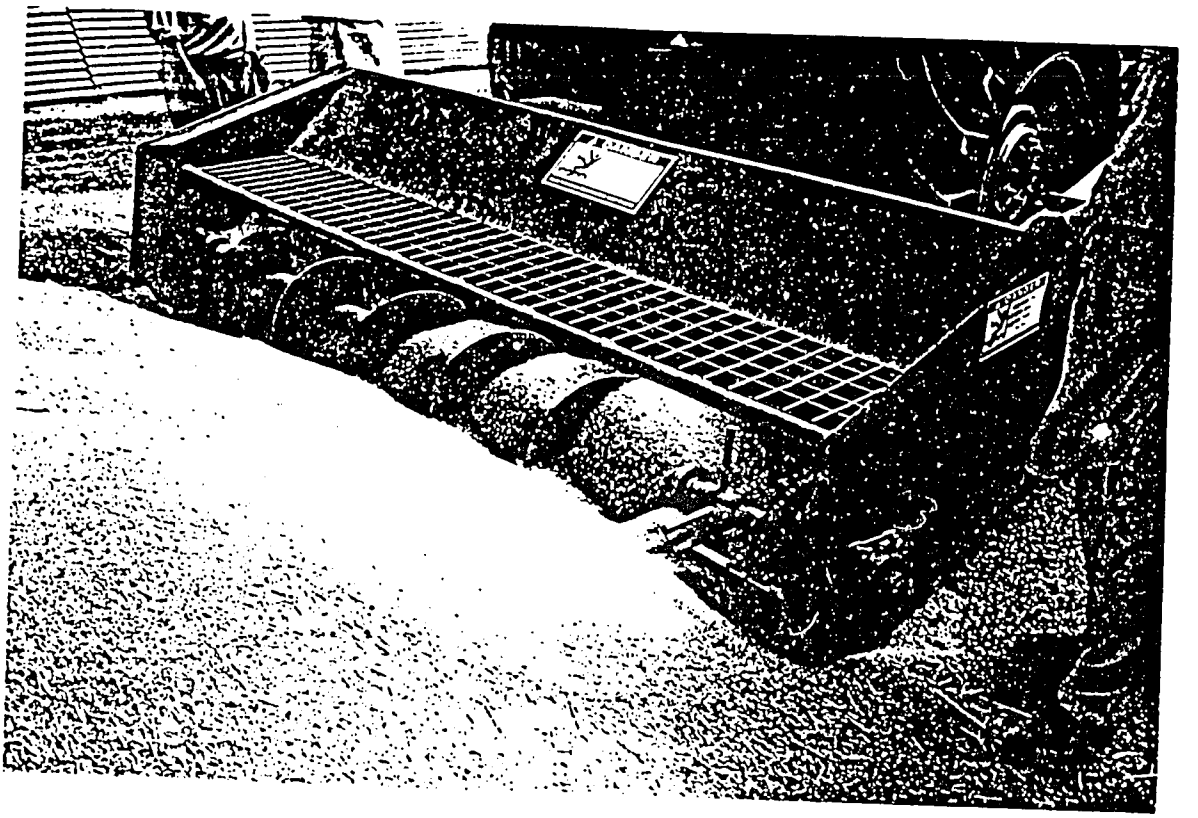

Figure 5. The feed hopper of a flat storage unloader shown retrieving grain from an open bulkhead storage.

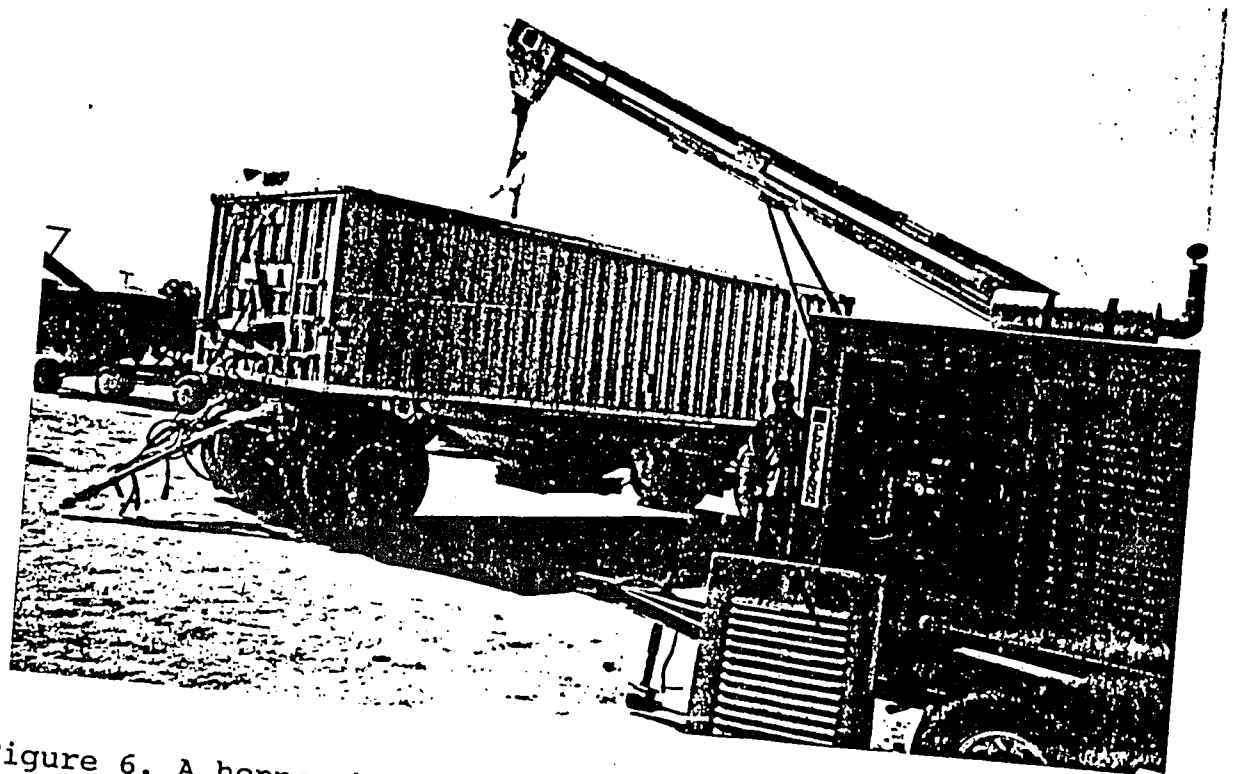

Figure 6. A hopper bottom bulk carrier used for long distance transport of grain from storage to millers.

Figure 7. A PASSCO self-tipping bulk truck delivering wheat to a local flour mill.

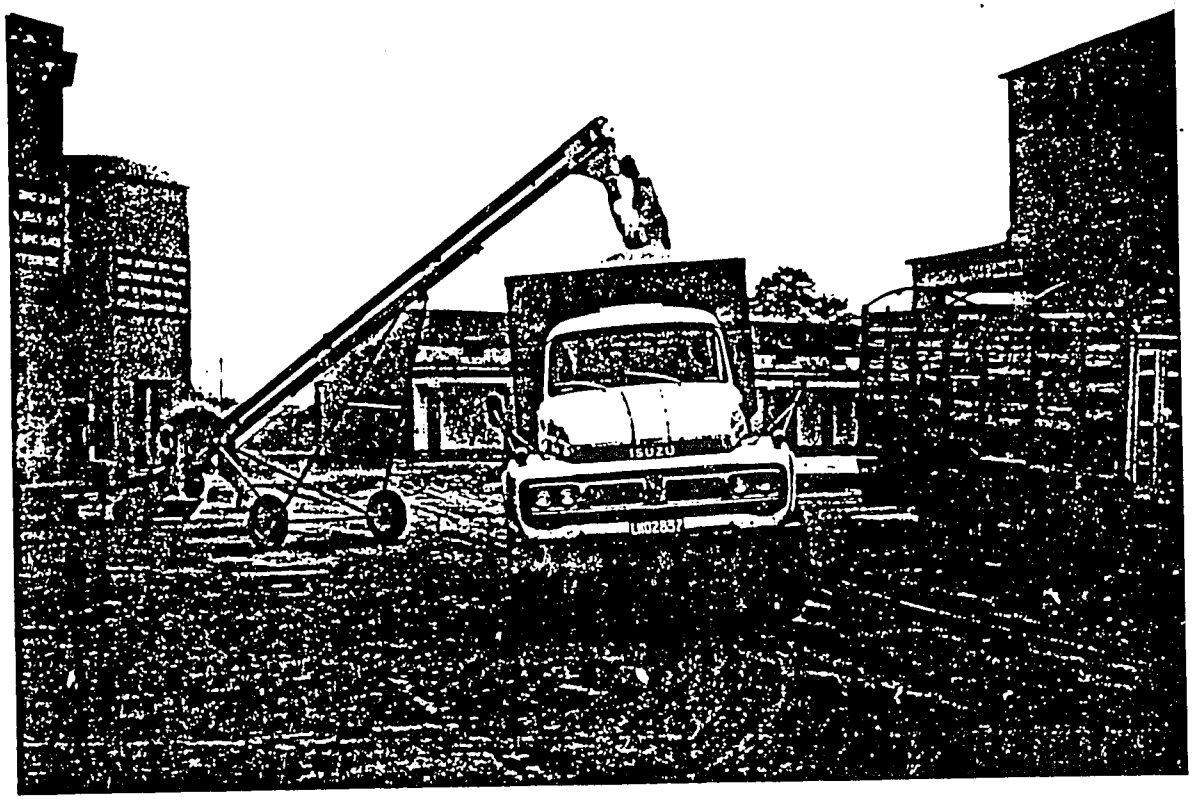

Figure 8. A portable chain conveyor (grain pump) shown loading a dump truck with grain from a hexagonal bin cluster.

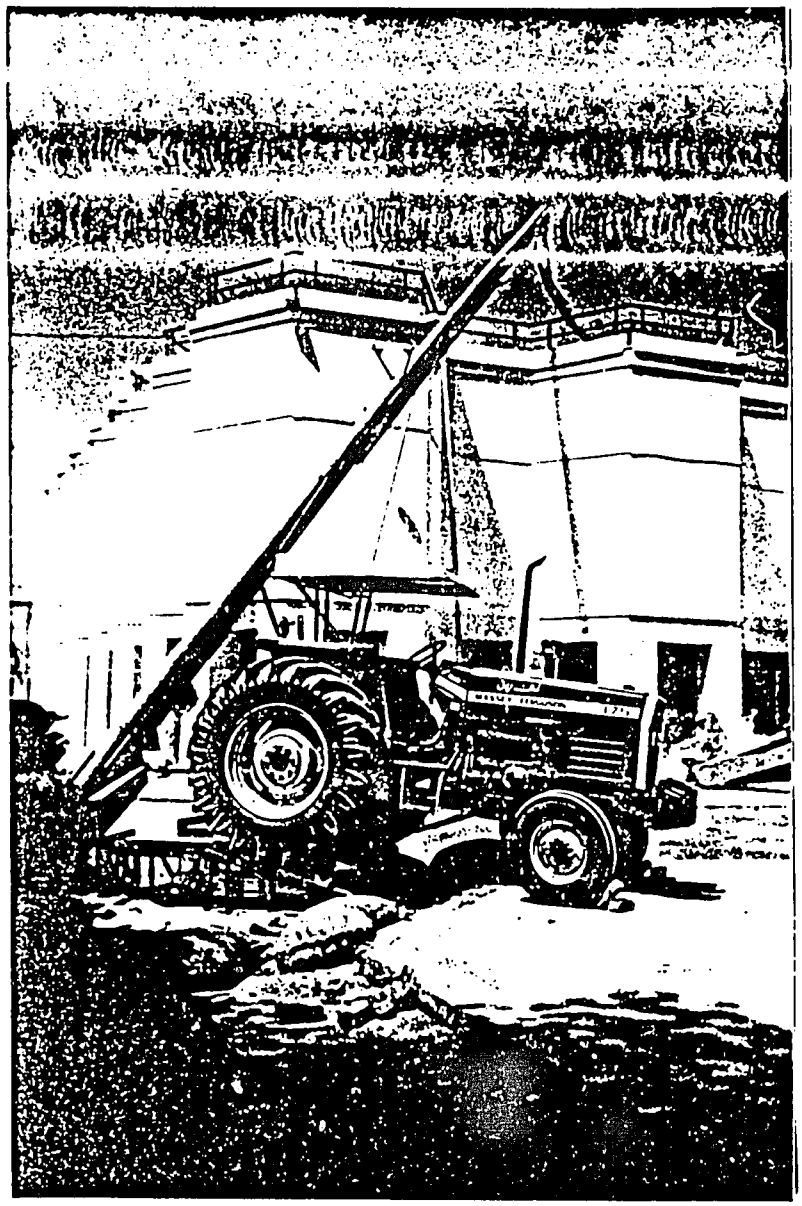

Figure 9. Picture showing the tractor-driven 65 feet portable grain pump filling a hexagonal bin.

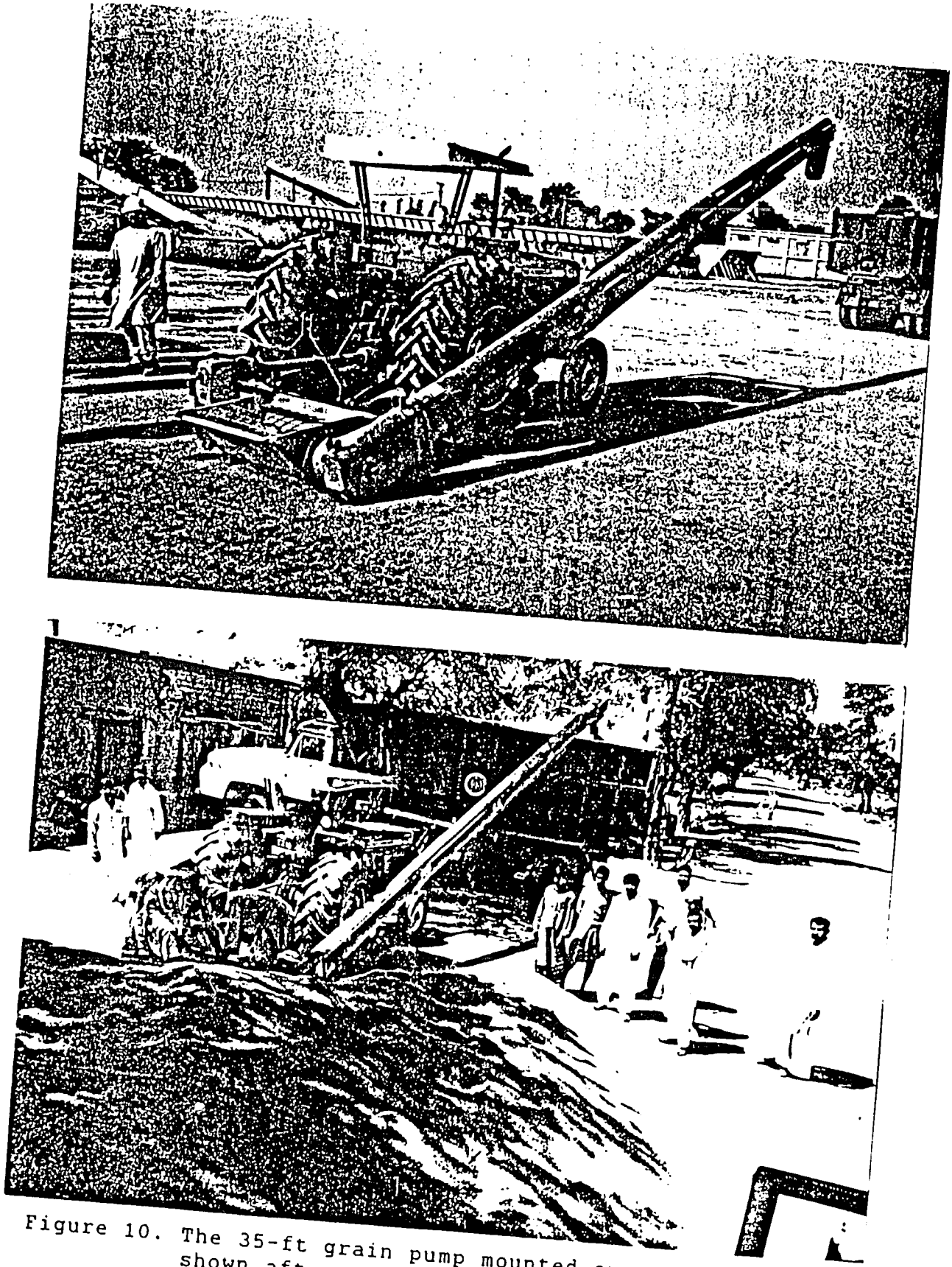

Figure 10. The 35-ft grain pump mounted on a farm tractor shown after mounting and while collecting bulk wheat by the roadside.

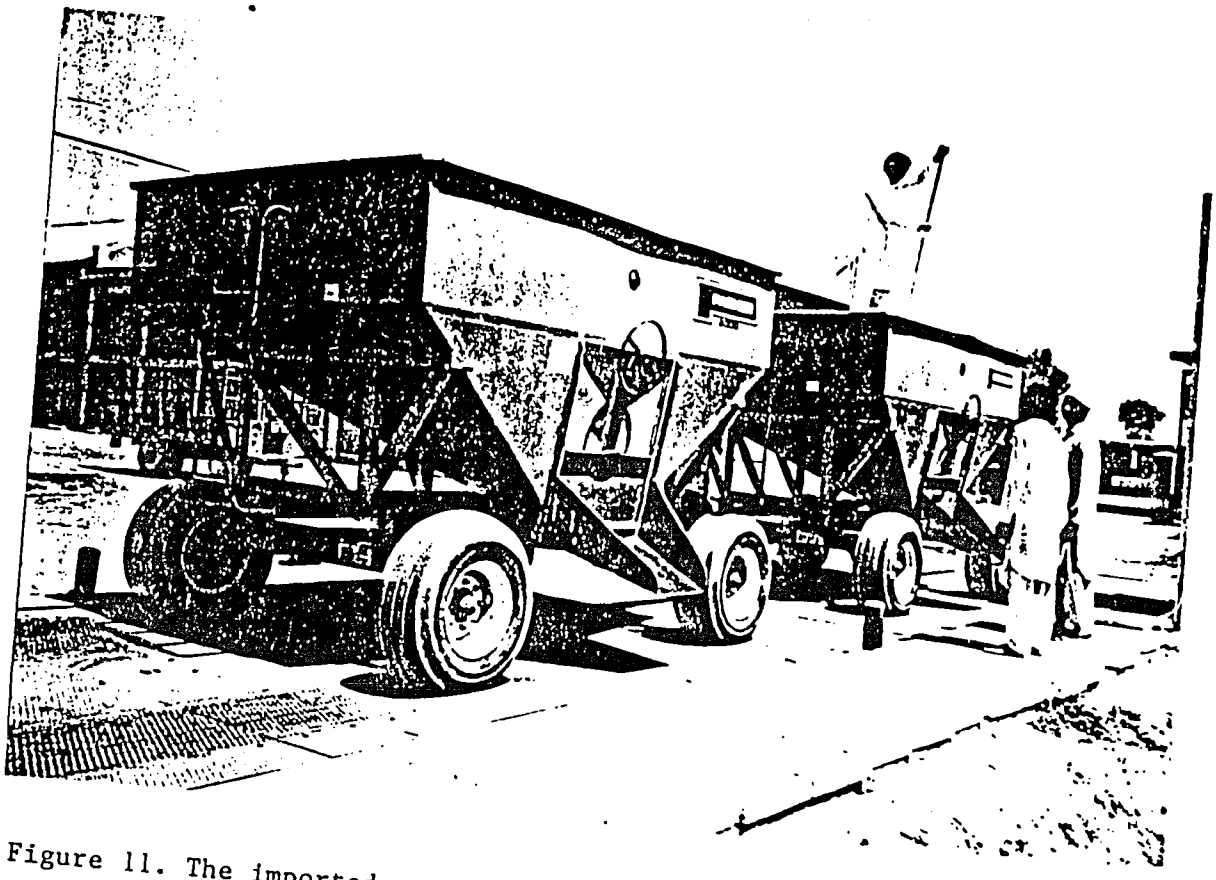

Figure 11. The imported gravity wagons used in transporting bulk wheat within a radius of 5 Km from the storage center.

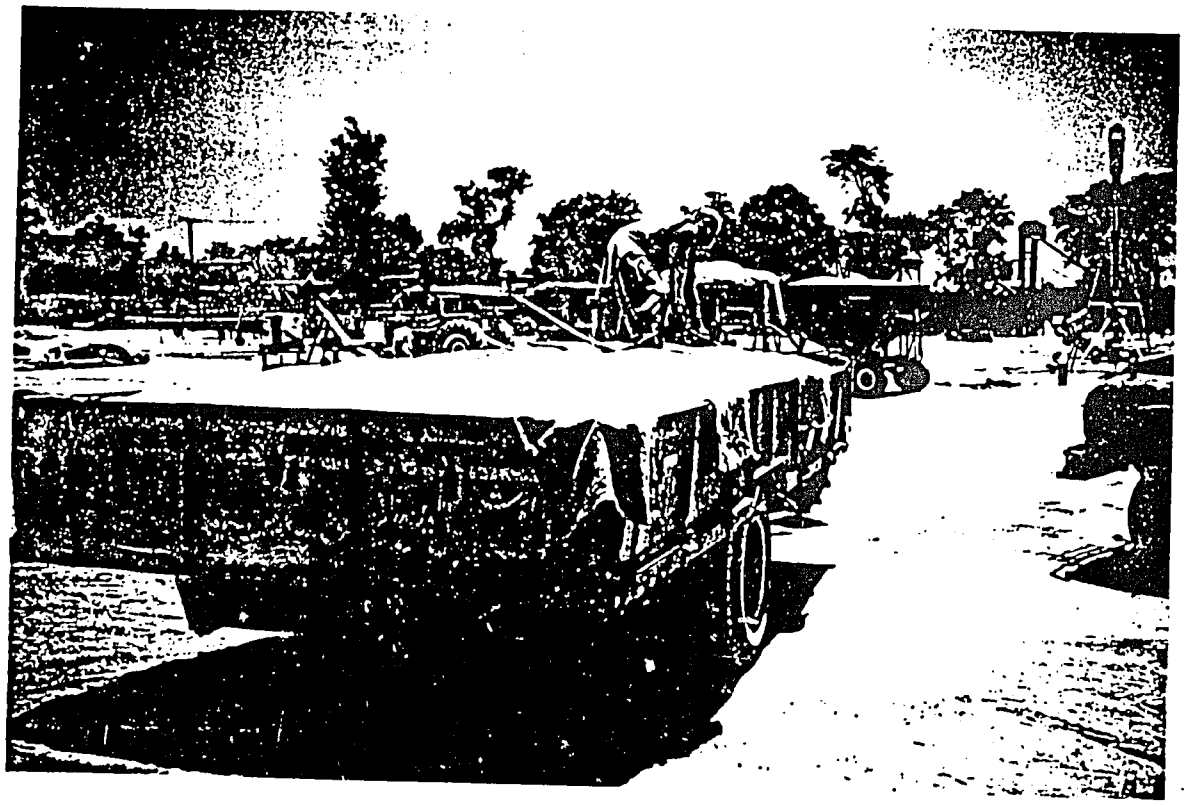

Figure 12. A locally made tractor trolley used by farmers to deliver their grain to the storage center.

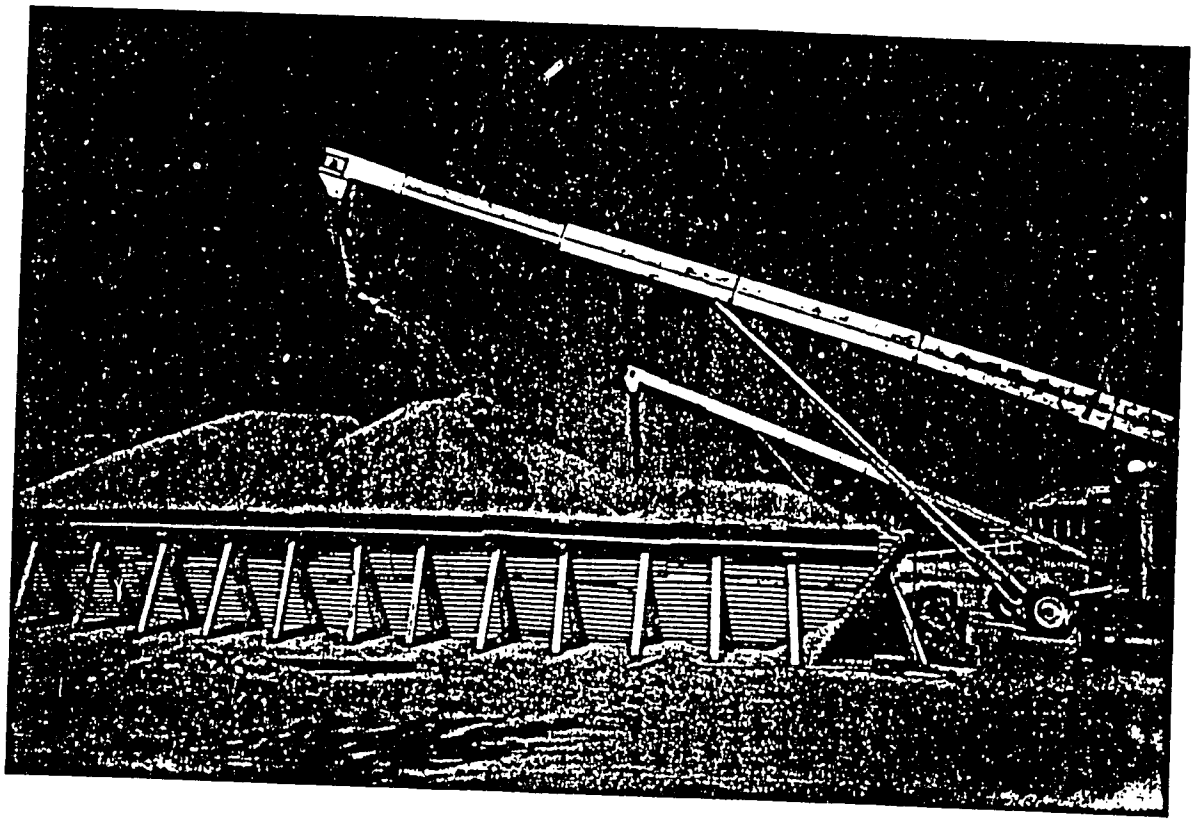

Figure 16. The commercial type portable chain conveyor shown with a set of bucket spouts used in spreading grain in the bulk head storage.

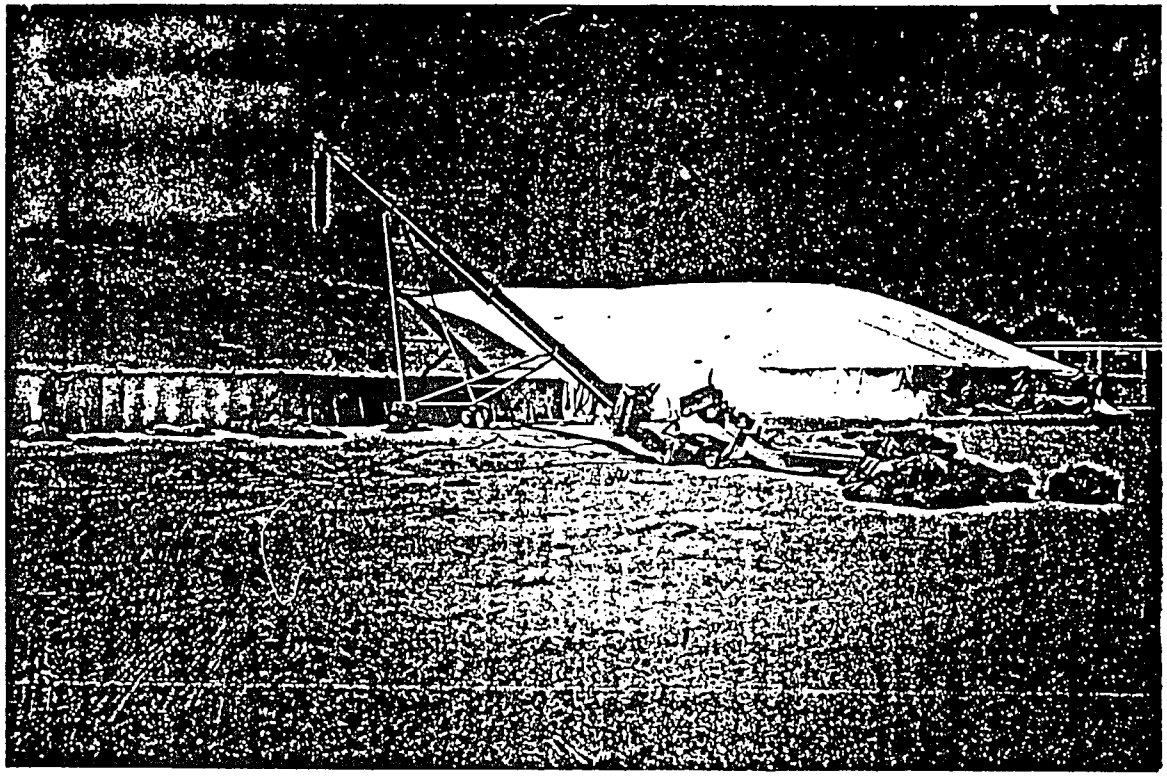

Figure 17. The commercial-type portable chain conveyor shown with an uncovered and completely covered bulkhead storage respectively.

BULK HANDLING ECONOMICS

Presentation to
Bulk Handling and Storage Seminar

by

Richard C. Maxon, STDT/FSM

Lahore, 17 - 19 June 1991

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Objectives of bulk handling research

The objectives of the bulk handling research are to:

-- Establish a bulk chain

(a) procurement center to storage center

(b) storage center to distribution center

(c) urban center to flour mill

-- Study

(a) economics of bulk and bagged handling

(b) physical performance of equipment

(c) grain protection methods in bulk

The operative word is research. The STDT/FSM bulk activities are to determine what is possible by using existing bulk handling facilities and equipment.

Putting the pieces together

Constructing a bulk handling system incorporating existing facilities is an entirely different proposition than developing an entirely new system. The initial estimate of overall savings from procurement to flour mills was Rs. 302 per mt based on 1985 costs.[1] The savings potential could be even greater today for a complete bulk chain. Savings with a partially bulk chain could prove to be less, but still sufficiently attractive to warrant adaptation.

The integration of existing facilities and personnel into a bulk system calls for compromises in system design and limits efficiency so that overall costs are affected. In setting up the bulk chain it is highly probable that cost increases at one stage of the chain will result in a reduction of costs at another stage. The investor may not reap the full rewards. For example, a high volume mechanical transfer point between storage and transport is more costly to build than a platform for stacking bags. The full benefit of this investment savings may not accrue to the firm that installs it unless it is in control of the entire bulk chain.

Under the present system in the public sector, six entities are responsible for the procurement, transport, and distribution of wheat: the four provincial food departments, MINFA, and PASSCO.

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[1] Borsdorf et.al. Bulk Wheat Handling and Storage Pilot Project in Pakistan. Food and Feed Grain Institute Report No. 2. Kansas State University, Oct. 1987, p. 114.

In the past, the federal and provincial governments made up any short fall in revenues for following policy directives related to procurement and release prices. This situation is changing so that all players are now conscious that one organization's savings can be another organization's costs.

For example, there are few incentives or benefits to protect grain in storage or maintain quality standards. Reducing expenses by not taking insect control measures reduces one organization's costs while imposing higher expenses on another further down the marketing channel. While bulk handling provides a means of enhancing quality through cleaning, sorting, blending, etc., there is no compelling reason to do so as long as the buyer, either another provincial food department or flour mill customer pays the same price for wheat of varying quality.

The present wheat flow illustrates the problem. Pakistan uses seven different storage types; four of which are bulk:

bulk - silos, open bulkheads, hexagonal bins, bulk-cum-bag

bags - godowns, gunjees, bini-shells

At present, the jurisdiction over the various stages has been of little consequence as long as expenses are ultimately covered by sources other than from sale of the wheat. As subsidies diminish, control of each step becomes more critical in controlling costs and obtaining funds for investment. As long as the user is not required to pay for capital costs, there is little incentive to worry about operational efficiency or the type of capital investment.

Behavior of bulk and bag handling costs

There are very few economies of scale in bag handling, the ratios stay nearly constant over the entire range of activities:

1 bag per 100/kg plus small amount of wastage

3 persons per bag: 2 to lift on back, one to carry.
Two persons lifting can service several carriers. There are usually seven to nine people in a work gang .

Costs tend to rise as volume increases - more persons, need more supervisors, tendency to get in each others way, slack off, etc. Cost of transporting workers to/from sites, etc. becomes factor when reaching out further for laborers.

Bulk handling is opposite. Heavy initial costs can be followed by low per unit costs with substantial volume increases. The marginal cost of increasing capacity does not rise proportionately to increase in volume. STDT prefers to use actual based on near optimum performance, but this is difficult to achieve on a sustained basis.

Bulk handling costs - performance

The results of this year's harvest are not fully accounted for this season due to the late harvest and lower than expected levels of procurement. Our equipment and crews are still in the field at this time.

For the first year of the bulk handling project, STDT, PASSCO, and the Food Department were concentrating on finding the right combinations of equipment. Some items did not arrive in time to be used in the 1990 season, notably the bulk dump trucks and 20T hopper bottom trailers.

To load godowns in bulk, STDT tried many combinations of equipment and had equipment built or modified as described by Dr. Acasio. During the present season, and forward to the end of the project, we are more or less standardizing on certain pieces of equipment - the 65' Masster-mover, for example, as the key item for loading hex bins and hatch equipped godowns.

Some relatively simple modifications made possible substantial reductions in equipment needs. To reduce costs of using an 80' inclined conveyor, the PASSCO truck was modified to permit dumping directly into hopper of conveyor, eliminating a truck unloader and generator. The trade-off was a slower performance. We have not yet completed evaluation as to relative costs of trade-off, but I believe it should favor the simpler direct flow. The extra equipment can be used in other places to enhance total productivity.

In observing the operations, it was noticed that off-truck flow was sometimes inconsistent - this will improve with experience as drivers and operators find best flow times. This is true of all interchanges between pieces of equipment and transport. For example, on filling hex bins, we must use tubes or extensions on the incline conveyors to reach hatches. As the angle of discharge is extended, the rate of the flow slows down. The lack of cleaning before wheat is stored slows down the rate of flow.

We tend to operate on the conservative side to reduce possible damage to equipment. Only one item, a broken bearing in a 65' grain has caused any operating time to be lost this year, and the problem was quickly overcome.

In 1990, with operation of similar equipment, the overall average direct operating expenses was Rs 86 per tonne loaded into bulkheads from bulk and bagged sources, including the tractors, gravity wagons, truck unloaders, and generators. However, direct operating costs of the tractor powered inclined conveyor was Rs 34 per tonne. We did not use the Trac-masster for bulk head loading last year. Its direct costs should be substantially lower due to its T/hr throughput.

It must be remembered that we are on the very upper end of the cost curve because annual depreciation and labor costs were charged to this very short season. Our attention is now shifting to using the same equipment for loading godowns, and reclaim to dispatch wheat on a nearly year around basis. The flexibility of the portable equipment should make mechanization of godowns feasible.

At the Manga Mandi demonstration, you will see how a godown has been fitted with roof hatches for about Rs 1,000 per hatch, or $10,000 per godown. This modest

investment will permit the 65' incline conveyor - which had a cost per ton of only Rs 11 last year on bulkhead loading, to be used to service a godown complex.

We now have lightweight tractors using one litre diesel per hour that provide the power and mobility for the inclined conveyor, eliminating the generator and larger tractors for shifting to new locations. Later on, the small tractor will be used in the reclaim operations as well.

Unloading of hex bins is slow because the discharge spout has a maximum rate of about 18 t/hr. It is possible that some simple devices will enable two or three hex bins to be discharged simultaneously into the reclaim conveyor to get maximum capacity from the unloading equipment and reduce loadout times.

Inter-provincial transfers in bulk

As the 1991 procurement season draws to a close, our attention is shifting to the inter-provincial transfer of wheat in bulk. An added incentive is the bringing on stream of the renovated Chichawatnee and Multan silos. A very recent development is the PASSCO participation in the reduced cost atta scheme to be operated by the Utility stores. In this program, PASSCO will have the authority to make deliveries directly to flour mills. Details have yet to be worked out, the opportunity now exists to test alternative transport arrangements.

Deliveries to flour mills

From December 20, 1990 to January 10, 1991, the Punjab Food Department, PASSCO and STDT delivered 1179 tonnes of wheat to flour mills in Multan. PASSCO served as contract carrier, receiving Rs 3.50 per tonne for wheat delivered in its newly acquired 15T dump trucks. This was slightly higher than the going rate of Rs 2.50 per tonne for bagged wheat deliveries. The receiving mills paid weighbridge and octroi charges.

The mills calculated their savings as follows:

Elimination of bag	Rs. 8.00
Elimination of interest for bags	.25
Unloading bags at mill	.60
Internal bag handling costs	.60
Savings per bag	9.45
Savings per ton	94.50

The costs for equipment operation have not been fully costed. The motivation for the deliveries was to clear out stocks from the Multan silo so that the renovation could proceed on schedule. Additional wheat deliveries to flour mills have also been made in Okara and Lahore.

SUMMARY

STDT has only preliminary costs from the 1990 and 1991 season to date. Thus far, the concentration has been on direct operating expenses for individual pieces of equipment. As we standardize on equipment and operating methods, it becomes possible to build up costs for the three bulk sub-systems, and a complete bulk chain.

THE CASE FOR BULK STORAGE AND HANDLING OF WHEAT IN PAKISTAN

by Jonathan Coulter
Marketing Economist

February 1991

Chatham, UK

SUMMARY AND SELECTED TABLES

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SUMMARY

Interest in bulk handling is growing in Pakistan, and has been spurred on the one hand by donor interest, and on the other by the perception that there is a growing labour shortage, making mechanization of grain handling a logical next step. The purpose of this study is to clarify the issues in favour of and against bulk handling and to define in what circumstances it is appropriate. The task is approached through economic analysis which looks at the costs to the country as a whole, rather than to the individual firms or parastatal companies involved in marketing wheat.

Pakistan's annual wheat output is nearly self-sufficient, but with population growing faster than production, it is becoming increasingly reliant on imports. About 60% of the marketed crop is procured and sold on to mills by the Federal and Provincial Government. All wheat is handled in bags, and most storage is likewise in bags. This system has been very successful in maintaining price stability and food security in Pakistan. However, it cannot be described as highly efficient, as it suffers from the following shortcomings:

(a) The low pricing policy has discouraged farmers from using more inputs and has made it difficult to achieve national self-sufficiency.

(b) It is a heavy burden on public finances, aggravating a large budget deficit.

(c) It is costly to the economy as a whole, due to logistical factors (the shifting allocation of procurement areas, the poor location of storage facilities, unnecessary handling at intermediate storage points, and a poor freight service on the railways), costly port handling, *ad hoc* official measures which inhibit private interprovincial trade, shortcomings in the system of labour contracting and sub-optimal use of capital assets.

(d) It is promoting phosphine resistance in insect pests of stored wheat and rice. This could lead to increased losses during storage and difficulties in exporting rice.

It is important that bulk handling is seen in its correct context. The above problems are mainly policy and institutional in nature and will not be solved by the introduction of bulk handling. Bulk handling may, in certain circumstances and subject to verification, contribute to a reduction in the cost of distributing wheat, but it would be most unwise to embark on a major programme of conversion to bulk without first resolving outstanding problems noted above. To do so would compound most of the logistical shortcomings of the existing system and under the present institutional arrangements would create a heavy management burden.

A number of silo complexes already exist in Pakistan but are mostly out of action due to problems of poor design, location, and maintenance. There have been several studies and project proposals for bulk handling and these were reviewed, but it was found that no convincing case has so far been made for a large-scale conversion to bulk handling or for the creation of bulk corridors from farmer to mill. Most studiers have adopted unrealistic assumptions about the benefits to

be derived from bulk handling, particularly with regard to the reduction of storage losses.

In considering what type of storage is required, it should first be asked: is any additional public sector storage capacity needed? It is estimated that the federal and provincial governments have available up to 4.4 million tonnes of covered storage capacity, far in excess of the amount of wheat the State needs to procure in order to effectively stabilize prices. If temporary open air storage is allowed for, the potential storage capacity is unlimited, though due to high losses this system cannot be counted on for storage of more than a few months.

However, many of the existing stores are poorly located; in the event of a thorough rationalization of the cereal marketing system, the Federal and Provincial Governments would probably wish to sell them off or lease them, and build new stores in more appropriate locations. At the same time, market liberalization will make it necessary for the private trade to build, lease, or rent suitable low-cost storage facilities. For these reasons it is sensible to consider the type of new storage structure required.

Various alternative bulk storage structures are considered including open bulkheads, silos of steel and concrete, bulk godowns and modified traditional godowns. These are compared to godowns with storage in bags, and in a mixture of bags and bulk (bag-cum-bulk system), as well as storage in permanent plinths which are designed and used so as to avoid the losses characteristic of the temporary structures. Bag-cum-bulk storage in godowns, with and without bulk handling, is also considered. These various storage structures are compared on the basis of cost and other criteria, including availability of local materials and relevant skills, physical protection, fumigability, reliability, and ease of management and operation. Consideration is also given to issues affecting the choice between bag and bulk systems in general, particularly the greater demands of bulk handling on management and skills, the social impact of eliminating bag handling (estimated to benefit upwards of 209,000 people in the procurement season and 39,000 during the rest of the year), and problems inherent in the use of bags (including opportunities for malpractice in their procurement and distribution).

An economic analysis is then carried out to assess the case for bulk handling, using the storage structures discussed, at different stages in the marketing chain, and involving different storage systems and transport modes (road and rail). From this analysis the following conclusions and recommendations emerge:

(a) For the immediate future, any additional long-term storage capacity should be in *permanent plinths*. With the possible exception of the open bulkheads, these are easily the most cost-effective storage structure, and are a less hazardous option than bulkheads (see Section 5.4). However, their use calls for improved storage practices and pest control techniques. It is recommended that work be started immediately to optimize the design and operation of the permanent plinth centres, and that no further bulkheads be acquired.

(b) The economics of bulk handling are very favourable to large roller mills operating in Pakistan, with economic rates of return of up to 71%. Large millers should be encouraged to store wheat in bulk, rather than in bags as they now do (see Section 5.5).

(c) Once mills have converted to bulk handling it will also be profitable to mechanize the reclaim of wheat from nearby storage centres which are already storing in bulk or using the bag-cum-bulk system (but without mechanizing loading operations) - see Section 5.6.

(d) Although STDT has made great advances in cheaply mechanizing the loading of existing godowns, the economic returns over and above simply mechanizing the reclaim are likely to be negative. This is because most of the equipment used in the procurement season lies idle for the rest of the year (see Section 5.6).

(e) STDT has also tried to mechanize the procurement of wheat from the farms, but in the location where trials were carried out the estimated benefit to cost ration in only 0.6. The case for mechanizing the procurement of wheat from public markets (mandis) is stronger, due to the faster turn around time, but the estimated benefit:cost ration is still negative at 0.9 (see Section 5.7).

The problem with mechanical handling form the farm is again the lack of out-of-season uses for equipment. However, it is possible that costs will eventually be reduced through the introduction of trailers with multiple uses, for transporting bulk cereals, cotton, fodder, sand, etc.

(f) Existing bag handling systems used for unloading ships at Port Qasim result in losses reported at between 2% and 5%, occasional demurrage charges, and ocean freight rates 10 to 15% higher than would be paid if rapid unloading facilities were available. There is an overwhelming case for a bulk loading and storage facility (see Section 5.8).

(g) Pakistan can secure massive economic gains by using unit trains to ship wheat between provinces, and thereby moving freight off the roads and reducing the very long turn around times which currently characterize railway freight (see Section 5.9). This can be achieved most economically if a large part of the wheat is shipped in bulk; in the case of imported wheat this would allow bags to be eliminated entirely from the distribution between port to mill. However, due to institutional factors, such a conversion is likely to take place slowly. Depending on the progress of the World Bank-assisted programme of railway modernization, it is recommended that the issue be subjected to more detailed techno-economic studies. Serious consideration should be given to the possibility of handling part of the wheat in unit trains but using an improved system of bag handling.

(h) Two more general conclusions can be drawn from this analysis. Firstly, capital intensive systems are not justified for long-term storage of wheat, where stock is only turned over once a year. For this reason one may question not only the building of silos but also of conventional bag

godowns, which have capital costs four times those for permanent plinths. Secondly, bulk handling cannot be justified by the reduction in the cost of handling labour, which in Pakistan is of minor importance, but rather by the more efficient use of other capital items such as ships, railways, lorries and, flour mills.

The high cost of bags is often advanced as a reason for converting to bulk handling, but here it is important to note an important difference between financial and economic analysis. Pakistan has the option of importing bags from Bangladesh at about two thirds of the cost of producing them locally, and it is the cost of the imported item and not that of the protected, locally made product which is therefore used in the economic analysis. The decision to protect the local bag-making industry is a separate issue from the decision whether or not to handle cereals in bulk.

An additional conclusion relates to the nature of the process by which capital investment decisions are made. The absence of systematic analyses of the pros and cons of different public sector storage and handling systems has sometimes resulted in less than ideal decisions. To remedy this, it is suggested that Ministry of Food and Agriculture (MINFA) creates a national planning team for cereal marketing and storage, involving key specialists in the following areas: agricultural economics and food policy; finance and accounting; storage technology and grain preservation; operational aspects. The team should be allowed to carry out such investigations as it thinks fit in pursuit of its objectives, and where appropriate to commission specialist consultancies.

ABLE 6: COMPARISON OF COSTS FOR NEW PERMANENT STORAGE FACILITIES, USING DIFFERENT STORE TYPES
(cost in Rs per tonne of wheat)

	Source in tables in Appendix F	With bag handling				With bulk handling				
		House-type Godowns With bag storage: 14 layers	18 layers	bag-cum bulk system	Permanent plinths	With Open Bulkheads High cost estimate	Low cost estimate	Concrete silos	Steel silos (low cost estimates)	Bulk godowns
a) At storage centre										
apital cost	F.2-F.8	189.5	148.9	126.4	29.1	96.8	51.1	252.7	149.6	155.8
aintenance	F.2-F.8	23.1	18.2	20.5	3.2	22.0	10.4	53.2	38.6	26.7
aterials cost	F.2-F.4	19.3	17.8	7.8	27.8	29.0	29.0	5.0	5.0	5.0
uel/power						1.0	1.0	1.5	1.5	1.5
abour										
unload/stack or pour		12.5	12.5	14.0	12.5	5.0	5.0	5.0	5.0	5.0
unstack or rebag/load on truck		5.0	5.0	8.0	5.0					
machinery operators						8.8	8.8			4.4
ags	F-1									
handling charge (1.5 extra handling)		11.4	11.4	11.4	11.4					
storage charge		11.6	11.6	11.6	11.6					
spillage losses (2 x 0.1%)		8.0	8.0	8.0	8.0	8.0	8.0			
ıb-total		280.3	233.3	207.6	108.6	170.6	113.3	317.4	199.7	198.5
›) At mill										
ıpital costs	F.12					4.8	4.8	4.8	4.8	4.8
ıintenance	F.12					1.6	1.6	1.6	1.6	1.6
ıel power						1.5	1.5	1.5	1.5	
ıbour										
bag handling at mill (Rs 5 + 2.5/tonne)		7.5	7.5	7.5	7.5					
2 machine operators for bulk unloading (Rs 2,000/month each)						.5	.5	.5	.5	.6
ıgs-2 extra handling	F.1	15.1	15.1	15.1	15.1					
›illege (0.1%)		4.0	4.0	4.0	4.0					
ıb-total		26.6	26.6	26.6	26.6	8.3	8.3	8.3	8.3	8.3
›tal		307.0	269.9	234.2	135.2	178.9	121.6	325.7	208.1	206.8

ıte: Costs "at mill", only include the difference between costs for bag and bulk system.

TABLE 7: COSTS FOR BULK CONVERSION OF A MILL, RECEIVING WHEAT IN BAGS (in Rs per tonne of wheat handled)

	Source tables in Appendix F	Incremental costs	Savings due to elimination of bag handling	Net savings from bulk conversion
Capital costs	F.12	4.8		(4.8)
Maintenance	F.12	1.6		(1.6)
Fuel/power		1.5		(1.5)
Labour				
bag handling at mill (Rs + 2.5/tonne)			7.5	7.5
2 machine operators for bulk unloading (Rs 2,000/month each)		.5		(.5)
Bags - 1.5 extra handling	F.1		11.4	11.4
Spillage (0.1%)			4.0	4.0
Total		8.3	22.9	14.5

TABLE 8: INCREMENTAL COSTS FOR BULK HANDLING OF WHEAT FROM RECLAIM AT GODOWNS
(cost in Rs per tonne of wheat)

	Source tables in Appendix F	Incremental costs	Savings due to elimination of bag handling	Net savings from bulk conversion
(a) At storage centre				
Capital cost	F.1[illegible]	4.1		(4.1)
Maintenance	F.[illegible]	1.5		(1.5)
Fuel/power		.5		(.5)
Labour				
Rebag/load on truck			10.0	10.0
Machinery operators		4.1		(4.1)
Bags - 1 extra handling	F.1		7.6	7.6
Total		10.2	17.6	7.4
(b) At mill				
Capital costs	F.12	4.8		(4.8)
Maintenance	F.12	1.6		(1.6)
Fuel/power		1.5		(1.5)
Labour				
bag handling at mill (Rs 5 +2.5/tonne)			7.5	7.5
2 machine operators for bulk unloading (Rs 2,000/month each)		.5		(.5)
Bags - 2 extra handling	F.1		15.1	15.1
Spillage (0.1%)			4.0	4.0
Sub-total		8.3	26.6	18.3
Total		18.5	44.2	25.7

TABLE 9: COSTS FOR BULK CONVERSION OF EXISTING GODOWNS (in Rs per tonne of wheat)

	Source tables in Appendix F	(a) Filling through the roof: Incremental costs	Savings due to elimination of bags	Net savings from bulk conversion	(b) Filling through doors: Incremental costs	Savings due to elimination of bags	Net savings from bulk conversion
(a) At Storage Centre							
Capital costs of civil works	F.2	130.3	126.4	(3.9)	154.4	126.4	(28.1)
Maintenance of civil works	F.2.1	21.2	20.5	(.6)	25.1	20.5	(4.6)
Capital cost of equipment	F.9, F.10	33.0		(33.0)	34.4		(34.4
Maintenance of equipment	F.9, F.10	11.8		(11.8)	12.5		(12.5)
Materials cost		5.5	6.0	.5	5.5	6.0	.5
Fuel/power		1.0		(1.0)	1.0		(1.0)
Labour							
unload/stack or pour			14.0	14.0		14.0	14.0
unstack or rebag/load on truck			8.0	8.0		8.0	8.0
machinery operators		7.9		(17.9)	8.7		(8.7)
Bags	F.1						
handling charge (1.5 extra handling)			11.4	11.4		11.4	11.4
storage charge			11.6	11.6		11.6	11.6
Total		210.8	197.8	(13.0)	241.6	197.8	(43.8)
(b) At mill							
Capital costs	F.12	4.8		(4.8)	4.8		(4.8)
Maintenance	F.12	1.6		(1.6)	1.6		(1.6)
Fuel/power		1.0		(1.0)	1.0		(1.0)
Labour							
bag handling at mill (Rs 5 + 2.5/tonne)			7.5	7.5		7.5	7.5
2 machine operators for bulk unloading (Rs 2,000/month each)		.5		(.5)	.5		(.5)
Bags - 2 extra handling	F.1		15.1	15.1		15.1	15.1
Spillage (0.1%)			4.0	4.0		4.0	4.0
Sub-total		7.8	22.6	14.8	7.8	22.6	14.8
Total		218.6	220.4	1.8	249.4	220.4	(29.0)

TABLE 10: COST-BENEFIT OF MECHANIZING THE COLLECTION OF WHEAT FROM FARM OR FROM MARKET

	Collection from farm	Collection from Market
Number of days worked per year	30	30
Number of trips per day	3	5
Quantity per trip	10.4 tonnes	10.4 tonnes
Total quantity collected per year	936	1,560
Benefits per tonne		
Bags - 2 handling	15.1	15.1
Labour on farm (Rs 1.25/bag)	12.5	12.5
Labour for pouring into hopper at storage center	5.0	5.0
Total benefits per tonne	32.6	32.6
Capital costs		
Grain pump	61,600	61,600
Hydraulic motor	13,475	13,475
Two 5.2 tonne trolleys	123,200	123,200
Less 50% cost of a conventional 11 tonne trolley - Rs 30,000	(15,000)	(15,000)
Total capital costs	183,275	183,275
Annual costs		
Annualized capital cost, assuming 10 year useful life	29,827	29,827
Annual maintenance costs - 5%/7.5%	9,164	13,746
Fuel costs for tractor while Loading, at Rs 0.5 per tonne	468	780
Labour costs:		
one machine operator and in charge Rs (4,500/season)	4,500	4,500
Three labourers to assist feeding of pump, at Rs 60 x 30 days	5,400	5,400
Total annual costs	49,359	54,253
Incremental costs per tonne	52.7	34.8
Incremental benefits	32.6	32.6
Benefit:cost ratio	.6	.9

TABLE 11: COST COMPARISON USING RAIL TO TRANSPORT WHEAT FROM SURPLUS TO DEFICIT PROVINCES
(cost in Rs per tonne of wheat)

	Source tables in Appendix F	With improved bag handling	With bulk handling	Net savings from bulk handling
(a) At Concentration Depot:				
Capital cost	F.13, F.14	20.8	40.9	(20.1)
Maintenance	F.13, F.14	5.8	9.3	(3.5)
Fuel/power		1.0	1.5	(.5)
Labour				
Unload from lorry/stack on pallet		5.0		5.0
Labour for loading rail wagon		5.0		5.0
Unload from lorry and pour			2.5	(2.5)
Machine operatives			1.0	(1.0)
Bags - 1.5 extra handling	F.1	11.5		11.4
Spillage (0.1%)		4.0		4.0
Sub-total		53.0	55.2	(2.2)
(b) At Railhead Distribution Depot				
Capital cost	F.13, F.15	20.8	35.5	(14.7)
Maintenance	F.13, F.15	5.8	9.3	(3.5)
Fuel/power		1.0	1.5	(1.5)
Labour				
Unload from wagon/stack of pallet		5.0		5.0
Labour for loading lorries		5.0		5.0
Machine operatives			1.0	(1.0)
Bags - 2 extra handling		15.1		15.1
Spillage (0.1%)		4.0		4.0
Sub-total		56.8	47.3	9.5
(c) At Mill				
Capital costs	F.12		4.8	(4.8)
Maintenance	F.12		1.6	(1.6)
Fuel/power			1.5	(1.5)
Labour				
bag handling at mill (Rs 5 +2.5/tonne)		7.5		7.5
2 machine operators for bulk unloading (Rs 2,000/month each)			.5	(.5)
Bags - 2 extra handling	F.1	15.1		15.1
Spillage (0.1%)		4.0		4.0
2Sub-total		26.6	8.3	18.3
Total		136.4	110.9	25.5

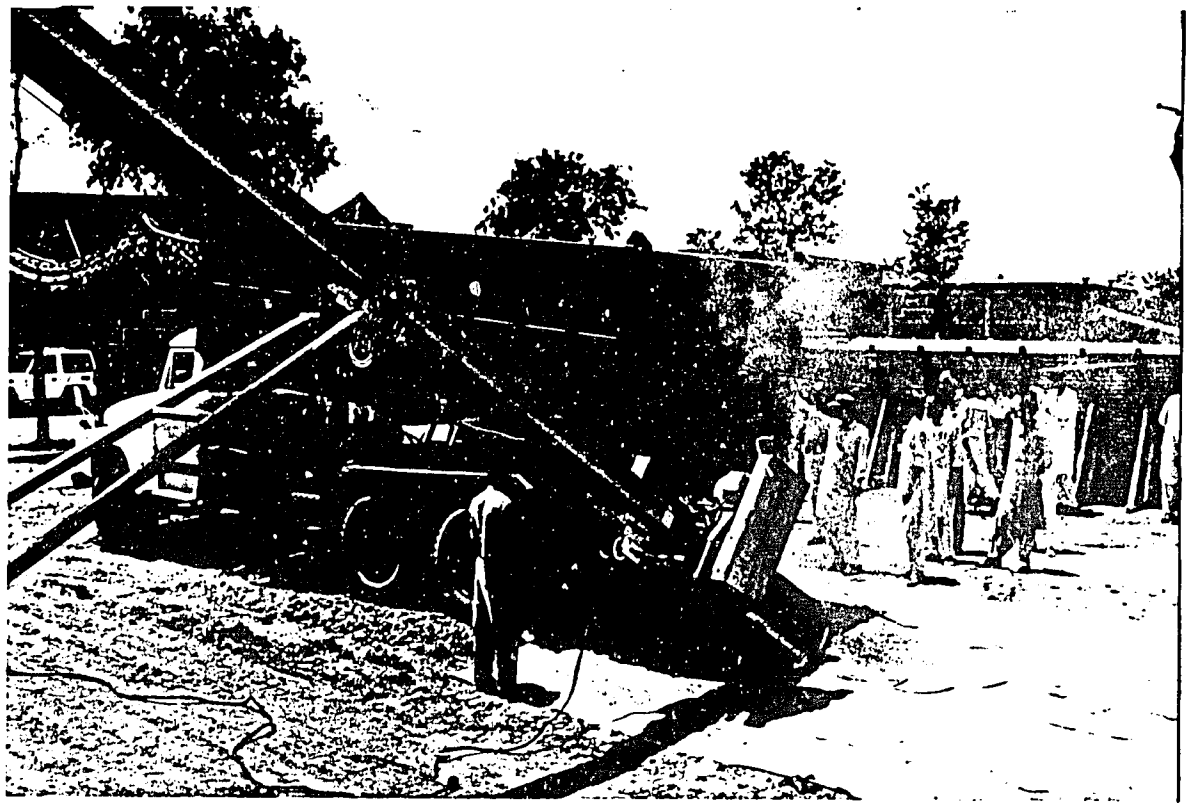
Bulk Wheat Handling and Storage Conference

Lahore, Pakistan
June 17-19, 1991

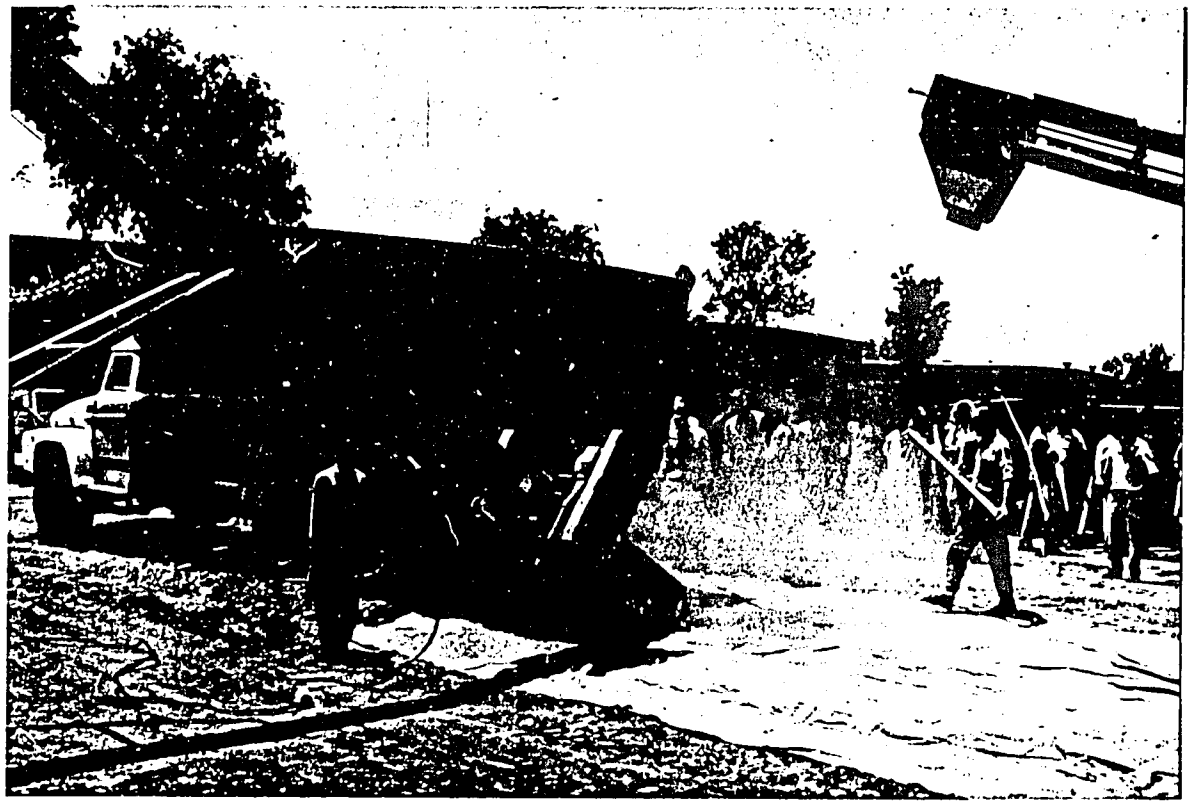
Bulk Wheat Demonstrations

Explanation of how PASSCO Godown was Converted to Bulk Storage System

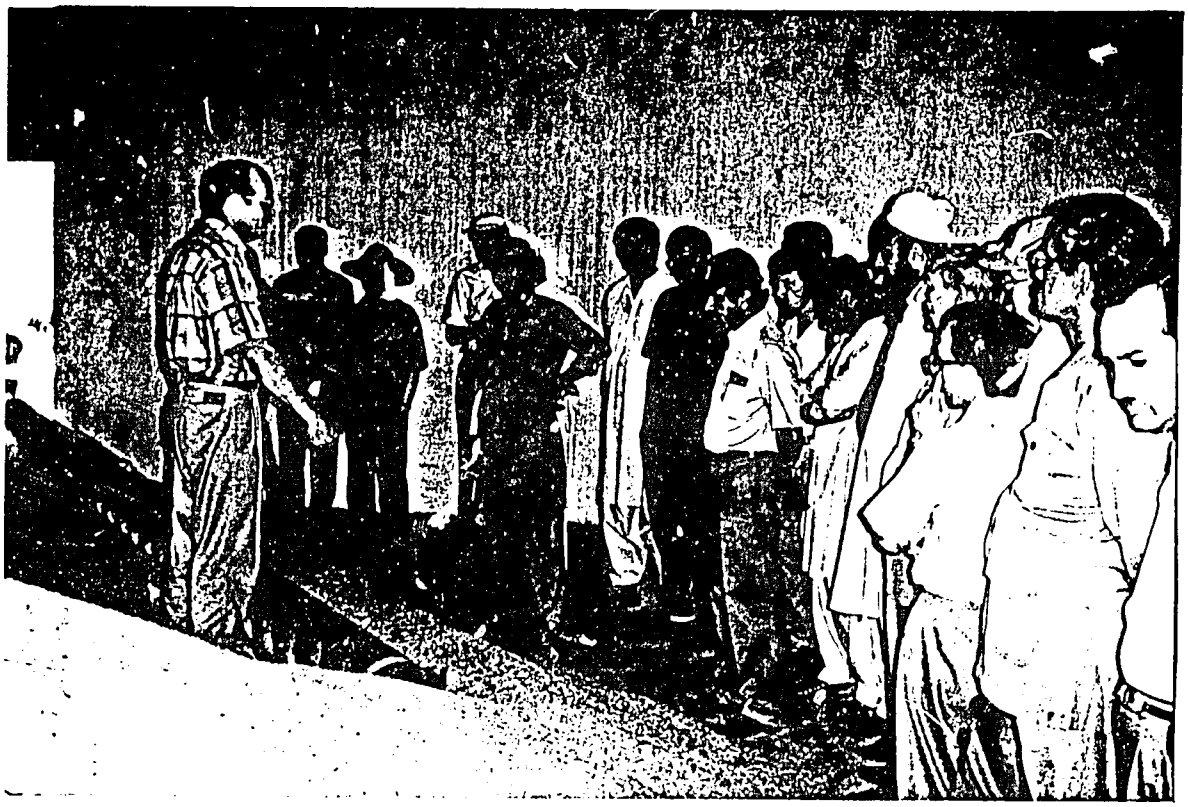
Loading PASSCO Godown with Bulk Wheat
Bulk Wheat Truck Unloading onto Bulk Wheat Conveyer



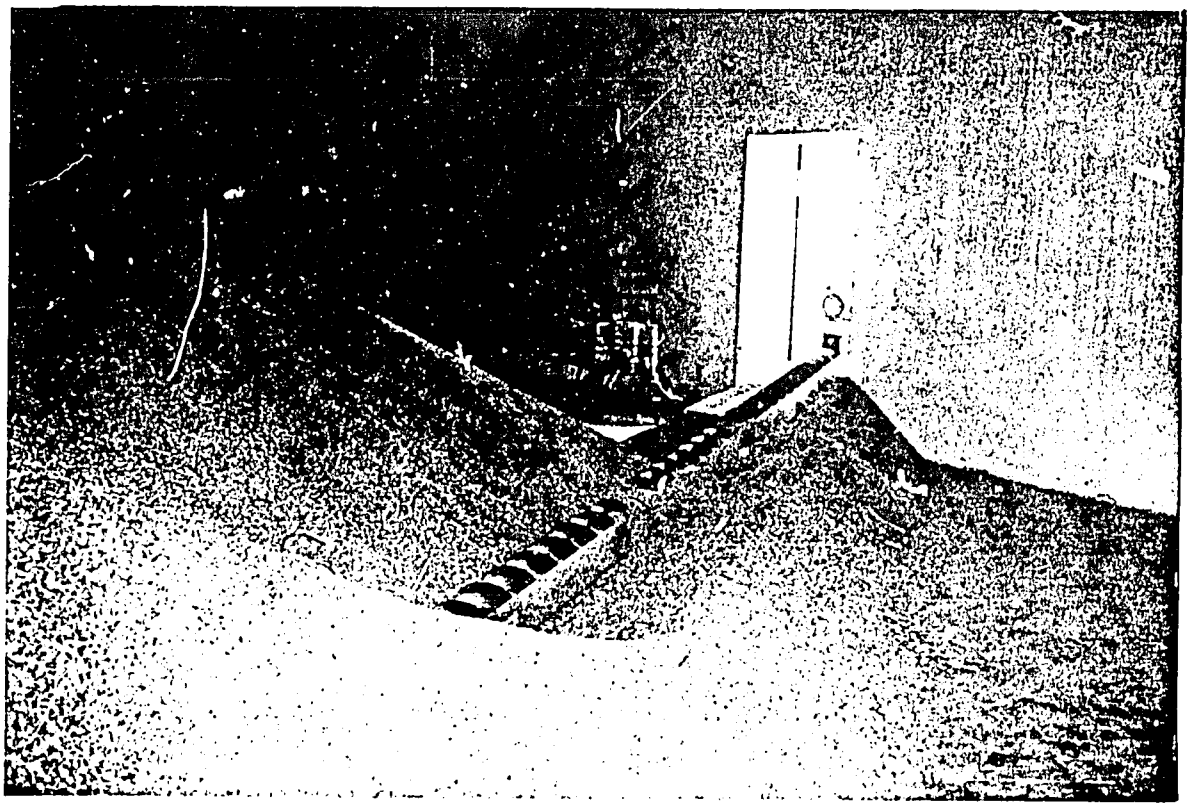
Loading PASSCO Godown with Bulk Wheat
Bulk Wheat Truck Unloading onto Bulk Wheat Conveyer



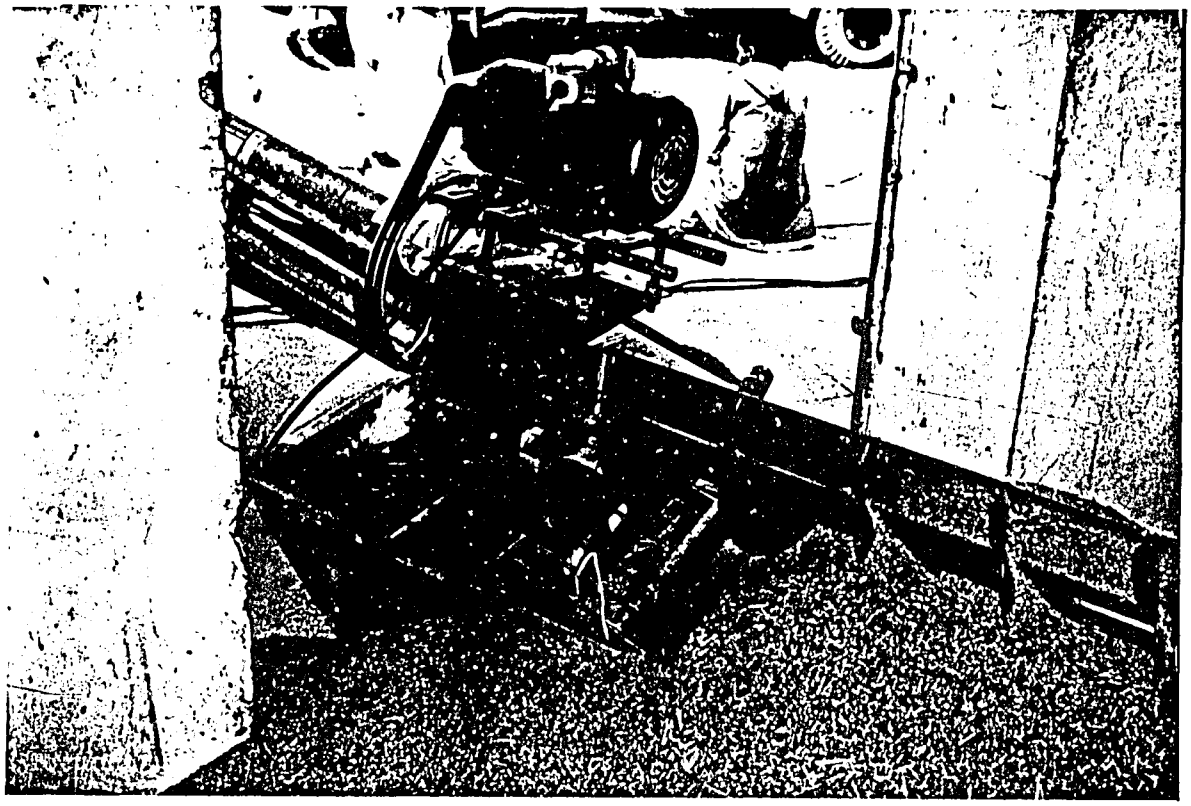
Loading PASSCO Godown with Bulk Wheat
Bulk Wheat Truck Unl· ·ding onto Bulk Wheat Convey: :



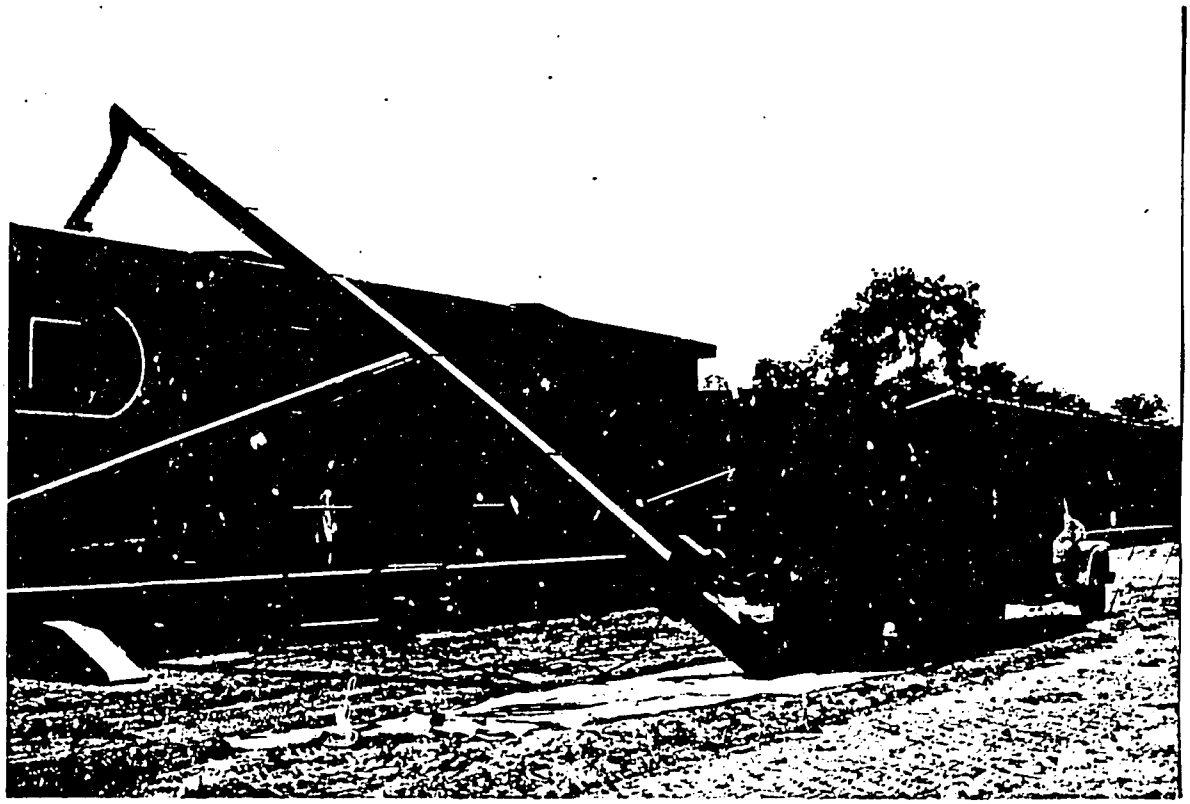
Explanation of How Bulk Wheat in PASSCO Godown will be Reclaimed by Sweep Auger



Sweep Auger Installation in PASSCO Godown for Outloading of Wheat



Outloading Bulk Wheat
Sweep Auger Feeding into the Hopper of Portable Conveyor which Loads Truck



Bulk Wheat Handling
Equipment Demonstrated