AGRICULTURAL
AND FOOD ENGINEERING
TRAINING AND
RESOURCE MATERIALS

2

ISSN 1996-2738

On-farm post-harvest management of food grains

A manual for extension workers with special reference to Africa

FIAT PANIS

AGRICULTURAL
AND FOOD ENGINEERING
TRAINING AND
RESOURCE MATERIALS

2

On-farm post-harvest management of food grains

A manual for extension workers with special reference to Africa

by

Peter Golob
FAO consultant

Edited by
Robin Boxall
FAO consultant

and

Stephanie Gallat
FAO Rural Infrastructure and Agro-Industries Division

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2009

The Agricultural and Food Engineering Training and Resource Materials make available to public sector institutions, universities, industry associations and NGOs, materials to support capacity building related to the application of technologies for value addition in the agrifood sector and their implications for policy. The series includes training manuals and resource guides that have been developed and tested through FAO's normative and field programmes.

ISBN: 978-92-5-106327-9

Contents

List of plates

List of tables

List of figures

List of boxes

Preface

This manual is intended to be a guide for extension workers. Its use should allow them to understand post-harvest issues concerning grains and, therefore, be able to advise farmers. For the purpose of this manual the term grain is used to include cereals (maize, sorghum, millet, wheat and rice), pulses and oilseeds. The term pulse refers to all kinds of legumes such as beans and peas.

The objective of the manual is to provide practical information on issues that occur during and following harvesting. The manual is not concerned with cultivation practices or with the control of pests during crop growth but it is primarily concerned with the storage of grain crops. However, cultivation, harvesting and other pre-storage issues that impinge on post-harvest quality are discussed, such as fungal and insect problems that occur once the crop has matured.

The manual is divided into four main sections. The first section describes the role of the extension worker in obtaining information regarding the specific problems faced by farmers and how to share and impart knowledge and advice. The second section deals with the major causes of deterioration such as moulds, insects and rodents, and how to prevent and control these losses. The third section describes traditional and improved types of storage, and the final section provides general recommendations for good storage practice.

Acknowledgements

We would like to express our appreciation to the Natural Resources Institute (NRI) UK, for providing many of the photographs and images that have been used to illustrate this publication. Thanks are also due to Robin Boxall for reviewing the report and his valuable comments and suggestions. Finally, special thanks to Larissa D'Aquilio for her thoroughness and patience in preparing this document for publication.

List of abbreviations

AIDS	Acquired Immune Deficiency Syndrome
DE	Diatomaceous earth
HIV	Human Immunodeficiency Virus
LGB	Larger grain borer
NGO	Non-governmental organisation
NRI	Natural Resources Institute (UK)

Chapter 1
Introduction

This manual is intended to help extension workers provide the best advice to farmers to enable them to store their grains safely, so that the quality of the grain is as good at the time of sale as it was at harvest. It provides:

- guidance on how to analyse farmers' problems and how to transfer knowledge and information most effectively;
- information on the major causes of deterioration in stored grains, including the influence of factors occurring before storage;
- description of common methods of storing grains on the farm and of improvements that can be made; and
- a summary of the basic principles of good post-harvest practice, including pest management.

Across the tropics and subtropics more than half of the population lives in rural areas. Most of these people depend solely on farming for their livelihoods. Nowadays, few farmers can be regarded as living truly at subsistence level, i.e. producing only enough food for their families and for seed. Most farmers now produce at least a small surplus for sale; the money obtained being used to improve their standard of living. The level of income depends not only on the quantity of crop sold but also on its quality. Hence, it is essential that farmers keep their crops in the best possible condition until they are sold.

The quality of the crop is influenced by many different factors. Most important is the length of time it remains in store. In most countries, food crops are harvested seasonally, and demand (and therefore price) increases as the new harvest approaches. Farmers can benefit from these increases by storing for long periods and then selling out of season. However, long-term storage increases the crops' susceptibility to deterioration especially by pests and diseases. Factors that influence the quality of the crops include:

- unseasonable weather and climatic conditions;
- type of crop, (cereals or pulses) and the crop variety cultivated;
- how the crop is harvested, threshed and dried;
- type of storage structure or container;
- processing methods, including drying and threshing; and
- management practices employed, such as pest control procedures and standard of store hygiene.

Farmers are influenced by a number of factors before deciding to sell their crops, such as the size of the harvest, the number of people to be fed, and the need for money. These issues determine when and how much grain a farmer will sell and must also be taken into consideration by the extension worker when offering advice. Unless the extension worker considers all such relevant information the advice offered may well be inappropriate.

Agricultural Extension Services need to tailor advice to meet specific, individual needs. This means that the extension worker will require knowledge of a range of solutions to fit a variety of different scenarios and skills in analysing the individual farmer's needs. It is no longer acceptable to simply offer one or two basic messages. The past failures of farmers to implement advice or to use 'appropriate' technology are indicative of weaknesses in the extension approach.

Chapter 2
The role of the extension worker

The responsibility for providing advice and information to farmers rests ultimately with the field extension workers, whether they are government employees or members of non-governmental organisations (NGOs).

There are several stages in the advice process, including:

- identifying the problems;
- prioritising the problems;
- finding out what the farmer really wants to achieve; and
- providing appropriate solutions.

Unfortunately, the training of extension workers at agricultural colleges does not always address the concept of problem analysis. Rather, it focuses on providing farmers with a small selection of officially recommended practices, often derived from research programmes that may not always take into account the different circumstances of the farmers. The recommendations, though technically sound, may be inappropriate, inconvenient or too expensive for some farmers.

Small-scale farmers, in particular, are rarely able to plan how to manage their crops from the beginning of the season. Rather, they have to make a number of decisions throughout the season, taking into account factors such as climate, personal circumstances, the prevalence of pests and the availability of inputs.

TABLE 1.
Examples of some of the decisions farmers may have to make for maize storage

Decision	Options
What type of store should I use?	Traditional basket (made from twigs, bamboo, twisted grass); crib; under roof eaves; floor of a room; platform; vertical frame; kitchen loft.
How should I store my maize?	On the cob with husk intact; without husk; after threshing.
Should I use insecticide?	Which insecticide? How much? Commercial or traditional insecticide? Dust or ash?
Do I treat my maize with insecticide?	No, if storage is less than one month; no, if storage is less than six months and larger grain borer (LGB) is absent; yes, if LGB is present.
I have no money to buy insecticide, what should I do?	Sell quickly if insects are present; use alternative treatments such as plant protectants, ashes and oil or smoke the crop; do nothing if insect pests are not present.
My maize is wet, what should I do?	Sun dry; thresh it as soon as possible; sell or feed to animals, use for brewing beer if drying not possible.
When should I sell?	What does my family need to eat; is the price likely to change; do I need money now; will I need some in the future?

Farmers therefore need valid information about all the options available to them. Thus, the extension worker must involve the farmers in analysing their problems and in identifying solutions that are appropriate and practical.

2.1 ANALYSING THE PROBLEMS

Storage problems are not simply restricted to what actually happens to the grain once it has been stored. Deterioration is caused by many factors that occur throughout the production cycle. The analysis of problems must include an assessment of the following:

- Crop husbandry: poor cultivation practices (e.g. inadequate weeding) may allow pests to survive and provide a source of infestation.

- Type of seed cultivated: some grain varieties, especially high-yielding ones, are more susceptible to insect damage. Open, loose varieties of sorghum and millet are more easily attacked by birds than tight-head varieties.

- Time of harvest: the longer the crop is allowed to stand in the field the more likely it is to be attacked by pests and diseases. The crop should be transported to the homestead as quickly as possible after harvest.

- Climatic conditions: rains at harvest time make drying difficult and grain will be prone to mould invasion. Drought conditions may also favour attack by some moulds.

- Post-harvest techniques (threshing, drying, winnowing): poor handling after harvest may damage grains making them vulnerable to pest attack; delayed or inadequate drying will also encourage mould and insect damage.

- Storage methods: types of storage structures (traditional and improved), pest control and storage management all determine the quality and shelf-life of the stored crop.

- Processing methods: flour has a shorter shelf-life than whole grains. When cereals and pulses are milled, the flour must be stored properly to prevent moisture uptake and insect infestation.

- Marketing and sale: where crops are intended for sale, the location of the farm, transport requirements and access problems must be considered.

- Causes and extent of losses: at which points in the post-production chain are significant losses occurring? What is causing these losses? What actions can the farmer take to reduce them to acceptable levels?

- Costs and benefits of post-harvest management: crop quality can be improved through good handling, storage and pest management. However, the costs of these interventions must be assessed against their potential benefits e.g. new market, higher price.

Once the crop is in store its future quality will depend on how well it is managed. If the store is in poor repair and allows easy access to rodent and insect pests the grain might deteriorate quickly. Poor quality structures will also allow goats, pigs and poultry to browse and eat the crop, and the crop may be accessible to thieves.

The farmer should be aware of these factors because they influence the length of time the crop can be stored and its ultimate use. Other factors that will have a bearing on how and when the farmer may have to act include: the local market price, the need for cash, and the family's grain requirements, whether for food, brewing or gifts.

Group discussions

Extension workers need to talk to groups of people as well as individuals in order to supplement information from past individual experiences and observations of cultivation, harvesting, storage and processing practices. This participatory approach to providing advice is likely to be time consuming and more difficult than promoting a single extension message. It is however likely to be more effective and result in better understanding of advice.

Within each community there are a number of different groups including: men and women; the elderly and the young; the wealthy and the poor; chiefs or leaders and elders; artisans; traders; the educated; and ethnic groups. To begin, all groups should participate in a general discussion of problems. This allows the extension worker to gain an insight into the important issues concerning the handling of the crops and to put them into perspective. The discussion will establish how important the issues are in relation to other agricultural activities and will also indicate the overriding priorities and what has greater and lesser importance.

Discussions with individuals

The initial discussions can help to identify quickly the most serious problems and to decide on possible courses of action. However, it may be necessary to work with smaller specific groups to examine the issues in more detail. Finally, individual farmers will need help in identifying actions that are suited to their own particular circumstances.

This approach will make more demands on extension workers who may be used to offering simply one or two generalized basic extension packages. The extension worker will need skills in interacting with farmers, observing farming practices, understanding the risks associated with potential solutions to problems and assessing the potential costs and benefits.

Advice for holding discussions

A detailed consideration of extension training and extension approaches is beyond the scope of this manual. However, the section that follows highlights some of the basic principles that extension workers might follow when assessing farmers' problems.

- For group meetings, planning ahead and selecting a time that is convenient for all participants.

- Keeping discussion groups small (between five and ten people) to foster participation.

- Being informal but respectful. Becoming familiar with the local customs and adopting appropriate dress code and attitude.

FIGURE 1
Farmer meeting

- Sitting together informally with the group. Explaining the purpose of the meeting. Observing local traditions regarding procedures for meetings.

- Encouraging people to talk. Listening actively and showing interest in what is said.

- Not patronizing farmers or making light of the issues raised.

- Using open questions that allow people to talk about issues. *Example: 'Tell me about the problems you have storing your grain', or 'What difficulties do you have getting your crops to your homes from the fields?'*

- Probing for details if the question does not produce enough detail. *Example: 'You said the insecticide was no good. Why was that? How much did you apply? How did you apply it?'*

- Keeping an open mind and avoiding preconceived ideas that may be outdated or inappropriate for the particular locality.

- Observing what happens in the village and taking time to look at the crops or the practices under consideration. This will help to focus discussion, avoid confusion and may reveal 'errors' in what people say. People may not want to reveal certain things for social or status reasons.

Encouraging participation in problem solving

Analysing farmers' problems is not simply about questions and answers. Farmers need to be involved and encouraged to take control of the discussion, with the extension worker acting as a facilitator, providing information, or prompting questions as necessary. There are certain techniques or 'tools' that the extension worker can use to help develop discussions and produce constructive conclusions. These tools are used to stimulate participation and can bring out local knowledge and the way that people look at specific issues. They help to highlight differences between people and different groups. These tools are also useful in developing extension approaches once solutions to problems have been identified. The following are examples of some of the tools that might be used during analysis of post-harvest problems.

Ranking - identifying alternatives
Farmers will have different decisions to make and some decisions will have more important consequences than others. It is therefore necessary to help the individual to prioritise the problems, so that available resources are used to the best effect.

For example, listing the harvesting and post-harvest practices for the various crops produced, then listing and ranking the problems related to each crop and practice. This approach should assist farmers in relating the importance of post-harvest problems to those that occur during cultivation or at harvest time. The technique can also help to identify the importance of individual crops, cash crops over food crops, and issues related to processing and marketing.

Mapping - where things happen
It is useful to know where activities occur within the community, and where different situations occur. For example, there may be an area where the crop tends to be damaged by rodents at harvest time. Mapping will show how farmers view their community, and it will indicate where different social groups live and where crops are cultivated.

Calendars - when things happen
Calendars can provide a picture of when activities occur throughout the year and show the busy periods when families are cultivating and the slack periods after harvest. It will be useful to know who is occupied at different times. A calendar will also show how post-harvest activities fit into the production cycle and when marketing occurs. It will identify times when crop prices are high and the best times to sell.

Transects - sampling across a community for information
A transect is a line drawn between two points in a village or community. The extension worker then walks the line to gather information by observation or from interviews with households. For example, a transect can show how common a storage problem is within a community. It can also show the distribution of specific groups of people and provide a snapshot of the village.

2.2 GIVING INFORMATION AND ADVICE

Various methods can be used to extend information and advice either to groups or to individual farmers. Farmers learn best when taught using informal techniques. Some of the methods are described below.

Discussions

Open discussions facilitated by the extension worker enable the experiences of a group to be put forward. Participants can consider options that may be new to them, for example, the use of locally available plants as storage protectants. These discussions allow those that have used a particular technology to describe it and to offer their opinions. They also allow people to draw their own conclusions and make their own decisions.

Flip charts

Charts with prepared diagrams can be used to illustrate a message. Blank sheets are useful to amplify an explanation or to record farmer responses during a discussion and can provide a record for recall in future training sessions.

FIGURE 2
Group discussions

Visual aids

Problems and solutions may be illustrated through the use of visual aids, which may include photographs, leaflets, samples of produce or insect pests, pieces of equipment, and packs of insecticide.

Example: displaying farmers' hybrid and local maize cobs that have very loose and tight husks respectively, can clearly and easily be used to explain why the former are so susceptible to insect attack.

Example: using actual specimens of insects can clearly illustrate which species are of concern.

Videos

Where suitable equipment is available videos can be useful extension tools. However, they are only short-term awareness aids and need to be supported by other material, such as leaflets and posters, to reinforce the message promoted.

Plate 1
Maize grain infested with larger grain borer adults

Posters

Posters may be used as visual aids during discussions but can be pinned up around the village to provide a permanent reminder of a message. Small booklets or leaflets given to farmers provide a similar function.

Demonstrations

There is no better way to explain how something works than by showing it in operation and observing the processes involved. For example, rather than just telling a group of farmers that their grain should be treated with 100 g of insecticide dust before it is placed in store, they can be shown how it should be done. Demonstrations allow opportunities to ask questions, to repeat operations if necessary and to become involved. For example, farmers might observe the construction of a storage structure, do some building themselves, and get answers to aspects they may not fully understand.

Drama, song and poems

These activities can be used to convey several messages but they are best reinforced by other training aids. They can be very effective as villagers can be involved as participants as well as forming the audience.

Decision trees

These are particularly useful when solving problems for individual farmers. The trees help to analyse the problems step-by-step, giving solutions for different scenarios that the farmers may face. They indicate what the farmers should do for any course of action they choose to follow. An example of a decision tree is at Figure 3.

Plate 2
Farmers participating in grain store construction

2.3 MONITORING POST-HARVEST DAMAGE DURING STORAGE

Discussions with the farmer will give the extension worker a good understanding of what the farmer believes is the situation regarding the stored crops. This is likely to be fairly accurate just after the grain has been put into store. However, as the storage season progresses, the farmer will know less and less of what is happening inside the store because it may be impossible to gain access to most of the crop. The farmer will not know what is happening deep inside the store and may well have a false impression of the situation.

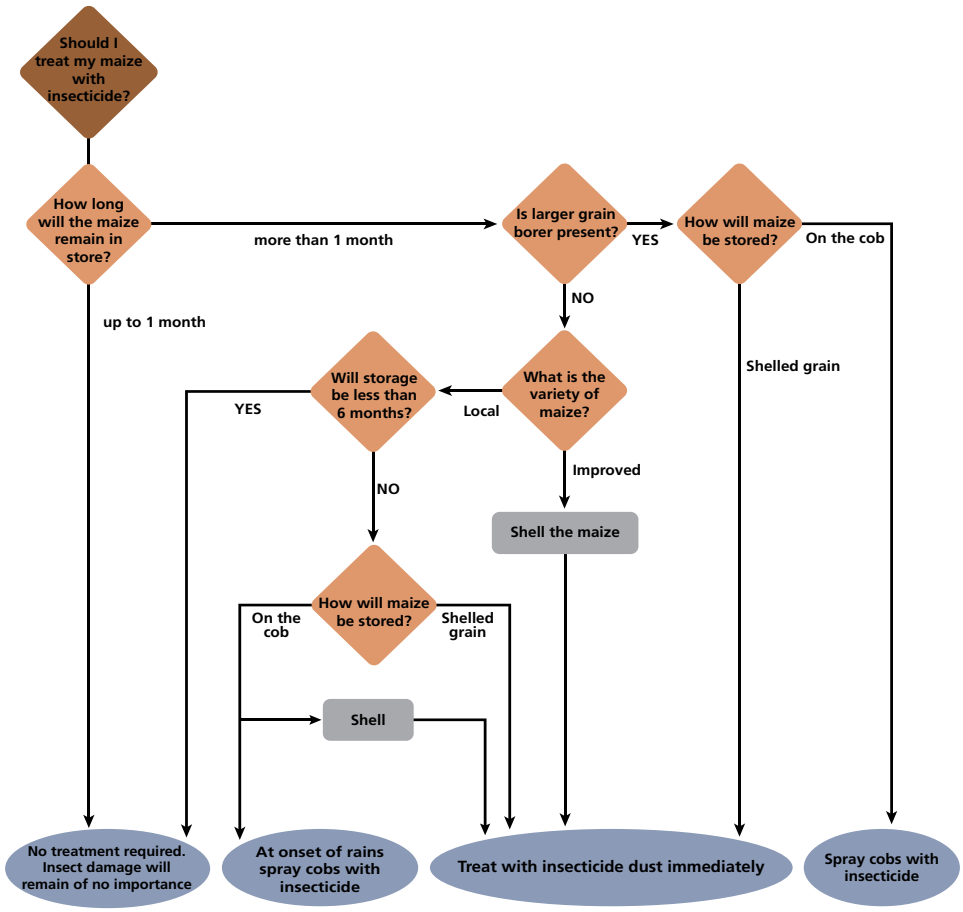
It is the extension worker's job to consider what might happen to the stored crop throughout the storage season. This can only be achieved by revisiting the farm at intervals, talking to the farmer and collecting samples to assess the progress of any damage.

Collecting samples must be done in the same way each time so that they can be compared. This means the same quantity of crop should be examined at each visit, whether this is 10 cobs or 1 kg of grain.

BOX 1
Storage insect behaviour

Storage insects, particularly grain weevils, tend to move down inside a store and eventually congregate at the bottom. They will not be seen by the farmer even when grain or cobs are removed for food preparation. As a result the farmer may not undertake any control measures so that much of the grain will be damaged.

FIGURE 3
Example of decision tree for maize in Tanzania



At each visit:

- One kg of grain is collected using a small bowl or tin. The sample should not be collected from the surface of the container, but the bowl should be pushed into the grain with the base uppermost. When it is deep inside the grain, the bowl is turned over and allowed to fill up. The bowl is brought to the surface and the grain poured onto a flat surface.

- This is repeated until about 1 kg has been collected.

- If maize cobs are collected 20 should be selected from various parts of the store. The grain is then shelled and heaped onto a flat surface.

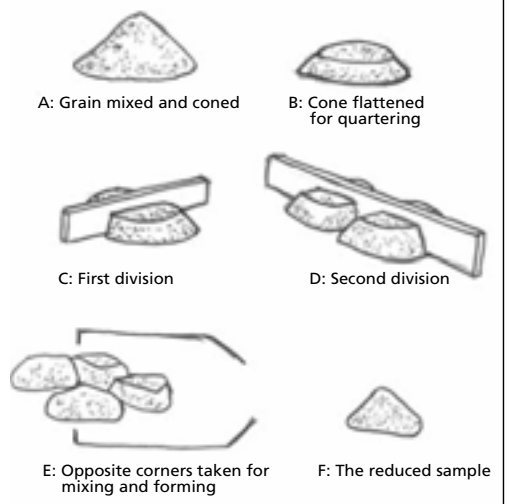
- The grain is mixed well.

- Using a small piece of wood or cardboard, the grain is coned and quartered as illustrated to obtain a sample containing about 200 to 300 grains. It may be necessary to cone and quarter the reduced sample again, especially with smaller grains such as wheat, gram, cowpeas and sorghum. The division does not have to be particularly accurate.

- At random, a sample of 200 grains is selected from the smallest heap and each grain examined for signs of insect damage, particularly holes.

- The number of damaged grains in this sample is counted. This number is divided by two and gives the percentage damage.

FIGURE 4
Coning and quartering grain to obtain a small sample



The sorting and counting can be done on a tray or better still by placing the grains inside a small grid, which can be made of wood or metal. It may be possible to use a small plastic titre plate (as used in hospitals or dispensaries). The grid should be about 10 cm x 10 cm and should be subdivided into 25 squares (5 x 5). Four grains are placed into each square so that when each is full there are 100 grains (with larger grains it might only be possible to put two into each grid). When the grid is full the grain in each square can be examined in turn for damage. Using the grid makes the process of estimating damage quick and simple and reduces counting error. The process can be repeated to complete the assessment of 200 grains.

Plate 3
Wooden grid containing 100 seeds

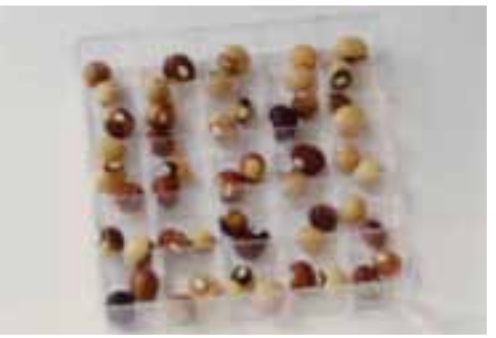


Plate 4
Plastic titre plate with 100 Bambara groundnut seeds

Chapter 3
Quality loss of stored grain and methods of prevention and control

The extension worker's job is to help the farmer keep the quality of the stored grain in the best possible condition so that the best prices can be obtained at sale. The principle causes of quality loss are:

- insects
- moulds
- rodents
- birds

3.1 INSECTS

Insects are usually the most serious storage pests. However, grain attacked by insects may still be eaten, unlike mould damaged grain, which may be completely unusable. Nevertheless, insect damage reduces the quality of the grain and therefore the market price.

Insects cause loss in weight and also in the nutrient content of grain so that there will be less food to eat and what remains will be less nutritious. Insects developing in grain produce heat, moisture and waste products. This can create conditions suitable for further deterioration, especially the growth of moulds.

Storage insect pests are mainly beetles or moths. Beetle adults are usually found crawling over the surface of grains while adult moths, if not resting on surfaces, are often found flying close to the store. Most damage is caused by immature (larval) stages, which mostly develop inside the grain.

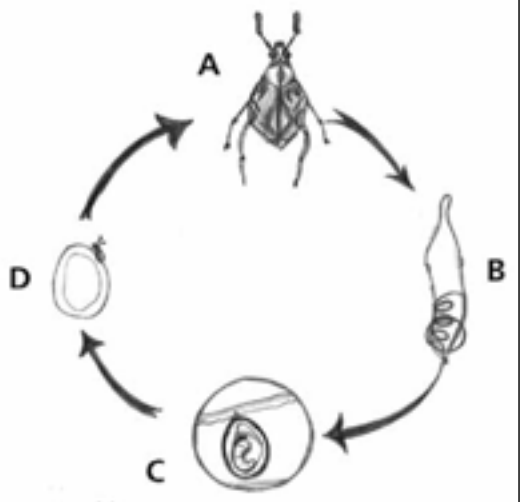
BOX 2

Maize value related to damage

It has been found with maize in Ghana that for every 1 percent damage above 5 percent, (damage being grains with insect holes), the value decreases by 1 percent. So if clean, undamaged grain is worth US$1.00/kg then grain with 10 percent damage is only worth US$ 0.95/kg, and that with 20 percent damage only US$0.85/kg. Similar though larger losses apply to pulses, which are generally of higher value than cereals. These potential losses in value can make a huge difference to a family's livelihood.

It is important to be able to recognize the most important insect pests and to have some knowledge of their biology and behaviour so that the appropriate methods of control can be used. Not all insects found in grains are pests. Moreover, beetles that attack cereals do not attack pulses and those that damage pulses do not infest cereals.

FIGURE 5
Life cycle of a bean bruchid



Insect pests that attack stored grains can be divided into two types: **primary pests,** capable of attacking and breeding in previously undamaged grains; and **secondary pests** that can only attack and breed in grains that have already been damaged or grain that has been processed into flour or a similar product.

Primary pests are very common in farm stores soon after harvest. In fact, they can occur in the plant once it has reached maturity in the field. Secondary pests tend to be most common once the grain has been damaged by primary pests and therefore are found after grain has been stored for several months. However, any damage to the grain that occurs during harvesting and threshing will assist in the development of these insects so that secondary pests may actually be seen early in the storage season.

The most common primary insect pests of cereals are the weevils, *Sitophilus* species. However, throughout much of Africa the larger grain borer, *Prostephanus truncatus*, has become the most important pest of stored maize in recent years. Smaller grains, such as rice, millet and wheat, are commonly attacked by the lesser grain borer, *Rhyzopertha dominica*.

Only one moth is found commonly in grain stores, *Sitotroga cerealella*, the Angoumois grain moth. It is frequently found in stores of cob maize, especially soon after harvest.

The most common secondary pests of cereals and cereal products are *Tribolium* species; *T. castaneum,* the red flour beetle is most prevalent in tropical and subtropical areas, and *T. confusum*, the confused flour beetle is most common in more temperate climates.

Some common insect pests of stored grain

Pulses are attacked by a family of primary pests, the Bruchidae or bruchids. There are three common species: *Acanthoscelides obtectus,* the bean beetle, *Zabrotes subfasciatus*, the bean weevil and *Callosobruchus maculatus*, the cowpea beetle. The first two mostly attack beans, particularly of the *Phaseolus* family, such as common beans, haricot beans and lima beans, whereas *Callosobruchus* attacks small grain pulses such as lentils, grams and cowpeas.

Plate 5
Maize weevil, *Sitophilus zeamais*

Plate 6
The larger grain borer, *Prostephanus truncatus*

Plate 7
Lesser grain borer, *Rhyzopertha dominica*

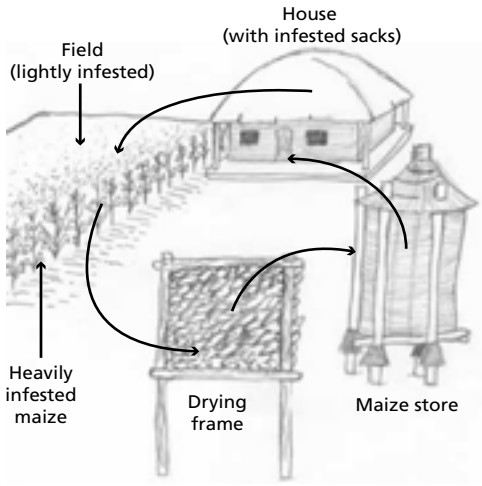
Plate 8
Angoumois grain moth, *Sitotroga cerealella*

Plate 9
Red flour beetle, *Tribolium castaneum*

Plate 10
Bean beetle, *Acanthoscelides obtectus*

Plate 11
Cowpea beetle, *Callosobruchus maculatus*

FIGURE 6
Insect infestation route



How do insects get into stored grain?

Insects can get into grain in a number of ways.

Some storage insects such as weevils lay their eggs on or in the grain as soon as it ripens before harvest, or while the grain is drying between harvest and storage. Similarly, bruchids can lay eggs on bean or pea pods, which are drying in the field. When the eggs hatch, the young larvae burrow into the grain or seeds. As the larvae develop inside the grain the infestation will not be noticed when the crop is put into store.

This field infestation can arise from grain residues left on the ground from the previous harvest. It can also arise when grain is stored near to the fields. Insects from the store can fly out to infest the ripening crop.

Some insects can fly from the fields into the grain store, especially if the store is close by. They can also fly from store to store in the village.

Farmers tend to use the same store year after year and if it is not cleaned, cracks in the structure may fill up with dust and pieces of broken grain. Insects can live on these grain residues from one season to the next. They can then emerge and attack new grain that is put into the store. The situation is made worse if the fields are used for cultivating the same crop year after year because the infestation cycle is never broken and the insects have a good, continuous supply of host crop.

The further the fields are from the homestead and, therefore, the grain store, the greater the chance of breaking the cycle of infestation.

Controlling insects in stored cereals and pulses

For convenience, control methods can be divided into two groups: non-chemical and chemical. Non-chemical methods of insect control are broadly considered to include any method that does not involve the use of conventional insecticides. They include traditional techniques employed by farmers and their forebears and may also involve the use of chemical substances other than the conventional insecticides specifically recommended for application to grains.

Many farmers use conventional chemical insecticides. Several chemicals are available which are approved for use as grain protectants by international organizations, such as the FAO. For application to grain, these chemicals are available as dusts or liquids sold under various brand names. It is absolutely essential to follow the application instructions on the container to ensure that the chemical is used safely and effectively.

Non-chemical methods of insect control

Crop rotation

Planting different types of crops in fields each year will reduce the problem of grain stores being infested by insects flying in from the fields. For example, after a crop of maize is harvested it could be followed by a crop of beans or cassava. Generally, of course, farmers growing a food staple do not have sufficient land to rotate crops in this way. As an alternative, they might try to intercrop or crop mix, so that maize is planted with beans one year and, perhaps, sweet potatoes the following year.

Early harvesting

The risk of storage insects attacking the crop in the field can be reduced by harvesting as early as possible after the crop has matured.

Selection of pest resistant varieties

Local or traditional varieties of cereals and pulses are usually more resistant to insect attack than new high-yielding ones. Local varieties may be stored for long periods while the high-yielding varieties may be sold earlier to avoid heavy insect damage. Experience will show which of the new varieties have some resistance to pest attack and these can be chosen for longer-term storage.

Maize cobs with good husk cover (thick, long and tight fitting husk) will suffer less insect damage. If maize is stored on the cob, selecting cobs with good husk cover at storage will help to reduce insect damage. However, cobs with the husk intact will take longer to dry than those without husks. This may be of no concern where harvest is followed by long periods of hot, dry weather but otherwise it could result in mould problems.

Thick husks, such as those of groundnuts and rice, generally give good protection against insect attack and these crops should be stored on farms with the husks intact. In crops such as sorghum and millet the husk provides no protection and other measures are needed to prevent insect damage.

FAO/10489/F.MATTIOLI

Plate 12
Good maize crop grown in pilot demonstration area of Mai Sa

© FGOLOB

Plate 13
Groundnuts in shell

Plate 14
Solarization

Exposure to high temperature – solarization

Insects can be killed by exposure to high temperatures during a process known as **solarization**. The infested grain must be spread out in a thin layer, less than 2 cm in depth, on empty jute or hessian sacks or on a sheet of black polythene. The grain should then be covered with a sheet of clear polythene, held onto the ground by stones. Exposure of grain to the sun in this way for two to three hours during the middle of the day will kill all the insects. However, if the grain layer is deeper than 2 cm not all insects will die.

If grain is just spread out on a mat on the ground and exposed to the sun very few of the adult insects present will die but they will instead move away from the grain as the temperature rises. The procedure may have to be repeated to give good protection. Sun drying is not as effective as **solarization** nor is it effective against the larger grain borer.

Admixing ashes or sand

The mixing of ashes or sand with threshed grains that are well dried is a popular traditional method of insect control. However, to be effective, large quantities (20 percent or more by volume) should be added to grain, which should then be shaken or stirred to ensure good mixing. Paddy husk ash can be used at 5 to 10 percent by volume because its silica content increases its effectiveness.

The ashes and sand form a layer over the surface of the grains, which prevents insect attack. They also fill the spaces between grains and act as a physical barrier preventing insect movement and reproduction. Before the grain is used the ash or dust must be removed by sieving, winnowing or washing.

Admixing inert dusts

Inert dusts or diatomaceous earths (DEs) are available in some countries for mixing with grain for storage protection. They are composed of very fine particles of aluminium silicate, which are obtained from naturally occurring diatoms, derived from riverbeds or the sea. They work by absorbing the wax from the insect's body, causing water loss, then desiccation and death. Unlike sand and ashes, DEs only need to be applied in small quantities, up to 0.2 percent by weight.

Treatment with vegetable oils

Some vegetable oils (e.g. groundnut, coconut, castor, cottonseed and palm) when mixed with grains provide some degree of protection against insect attack. They need to be applied at more than 1 percent by weight to provide protection for several months. As these oils are mostly used for cooking they are relatively expensive if used as grain protectants, except when applied to high value commodities or for small quantities of seed. Treatment of pulses can be very effective; however, grain coated with oil is awkward to handle and may be difficult to sell.

Plate 15
Neem, *Azadirachta indica*

Plate 16
Dalmation Pyrethrum, *Tanacetum cinerariifolium*

Smoking

Maize cobs and unthreshed cereals and pulses can be stored on platforms or in the loft of the house above a fire. The smoke and heat from the fire may kill insects or drive them out of the grain. The method is not always effective; in particular the larger grain borer will not be killed.

Adding dried or fresh plants

A traditional method of grain protection is to mix dried or fresh parts of plants with grains before storage. Leaves are added more frequently but roots and seeds may also be used. Leaves may be steeped in water to produce a dipping solution or spray. They may be dried and powdered and simply mixed with the grain, or they may be added fresh to sacks of grain. Roots and seeds are usually first dried then powdered before use.

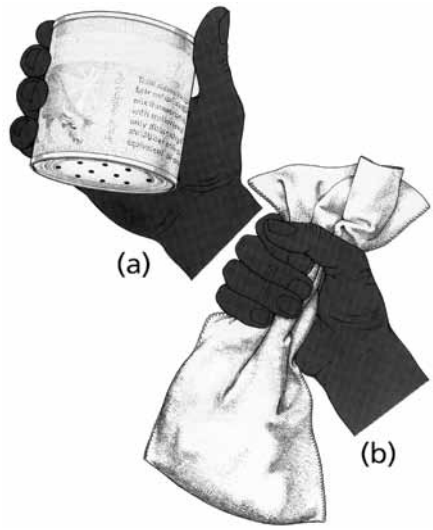
Numerous plants are used in this way, the most common being neem and pepper. However, the practical effectiveness of most of the plants used as insecticides is not well known. The one exception is Dalmation Pyrethrum (*Tanacetum cinerariifolium)* from which pyrethrum is extracted for use in the control of malaria mosquitoes, as a domestic fly spray and as a grain protectant.

Caution must be exercised when using plants to protect food grains. Many of the plants used traditionally are weeds and contain chemicals that are toxic to humans and livestock as well as to insects. In high doses, accidental poisoning might occur. Such plants should be used only to treat seed grain or unthreshed crops; the husk should not then be fed to livestock. A good example is the tobacco plant, which contains the poison nicotine. Nicotine is extremely toxic. Therefore, when dried powdered tobacco leaves are added to grain as protectants, this grain must be reserved for seed only.

Chemical methods of insect control (insecticides)

Insecticides, when properly applied to stored cereals and pulses as dusts or sprays can offer long-term protection against insect attack. Insecticides are usually applied to dry threshed grain. This minimizes the amount of insecticide required and provides good protection. It can be difficult and expensive to apply insecticides to maize stored on the cob or to other unthreshed cereals and pulses, and treatments may not be very effective in preventing insect damage.

FIGURE 7
Insecticide sprinklers made from (a) a tin and (b) a piece of sacking



BOX 3
Appropriate use of insecticides

Only those insecticide dusts that are labelled for mixing with food grains must be used to protect grain; *dusts labelled for treatment of seed grain should never be mixed with grain intended for food.*

Insecticides should be applied as early as possible as delays will reduce effectiveness. Larvae developing inside grain are almost immune from the effects of insecticide dusts and will not succumb until the young adult emerges. Delayed treatment results in greater insect damage.

Small quantities of grain, up to two tonnes, can be treated using insecticide dusts. Unthreshed crops, such as maize cobs or sorghum heads, can also be treated with these dusts but the use of liquid insecticide sprays is more convenient. Farmers who produce larger quantities of grain may need to have their produce fumigated to ensure that it is free of insect pests. Fumigation should not be undertaken by the farmers themselves but should be carried out only by trained personnel.

Insecticide dusts

Insecticide dusts are recommended for use by the small-scale farmer because they are:

- safer to handle than some of the more concentrated formulations as they contain a low concentration of insecticide (up to 2 percent);
- ready to use and do not require mixing or dilution;
- supplied in small packets making the calculation of dosages easier; and
- relatively cheap.

The instructions given on the packet will specify how much powder to use. The packets usually contain sufficient powder to treat one or two bags of grain. Insecticides must be applied at the recommended rate stated in the instructions. If too little is used it will be ineffective. If more than the recommended amount is used it is wasteful, it will not kill more insects and the grain may not be safe to eat.

Dust sprinklers

Insecticide dusts must be applied evenly, ideally using a sprinkler. This can be made from a clean tin with a well fitting lid; a dried milk tin is ideal. About ten holes should be made in the lid of the tin using a 5 cm nail or similar pointed tool.

Another type of sprinkler can be made from an old sack. If a piece of sacking, 60 cm x 40 cm, is folded in half and two open sides stitched together a simple bag can be made.

Insecticide applied from the tin or bag by gentle shaking will settle as a fine layer of dust on treated grain or store surfaces.

How to mix insecticide powders with threshed grain

- Grain must be clean and dry.
- If the grain is already infested, dust, insects and damaged grain should be removed by sieving or winnowing. The rubbish should be burned.
- Grain that will be needed for immediate use or consumption should be put aside.
- Quantity of grain to be treated and how much insecticide will be needed should be estimated.
- A suitable powder sprinkler that can hold the right amount of insecticide for the grain to be treated can be made.

BOX 4

Calculating insecticide quantities

The farmer has 20 sacks of maize, each weighing 50 kg and needs to treat each sack with Actellic 2% dust. The label on the insecticide packet says apply 50 g of dust to every 100 kg of grain.

The farmer needs to treat 20 x 50 kg = 1 000 kg of grain.

If 100 kg of grain has to be treated with 50 g dust, then 1 000 kg requires 500 g of Actellic.

If each packet of Actellic 2% contains 100 g of dust, then the farmer will need 5 packets.

There are two methods for mixing insecticide dusts with grain:

- mixing with a shovel;
- layering insecticide with grain in store.

Mixing with a shovel

This is a quick, easy method for mixing powder with grain heaped on the floor. If the floor is concrete, the mixing can be done on the floor itself. If the floor is made of earth, the grain must be emptied onto a polythene or metal sheet or onto a tarpaulin spread on the floor, and not onto bare earth. The method depends on the quantity of grain to be treated.

Method A can be used to treat up to 100 kg at a time. Method B can be used to treat up to 500 kg at a time by one person or up to 1 000 kg if two people are involved.

Method A

- The floor, sheet or tarpaulin should be swept before starting to pour the grain from the sack.
- The grain to be treated is poured into a heap on a clean floor, sheet or tarpaulin.
- The amount of insecticide dust needed to treat the heap of grain is put in the sprinkler. All the insecticide dust is sprinkled over the surface of the heap.
- A clean shovel, hoe, bowl or piece of flat wood is used to gently mix the insecticide powder into the heap. The heap is turned until all the grains are evenly coated and no patches of powder are visible.
- The treated grain is stored in a clean bag or container.

Method B

- The floor, sheet or tarpaulin should be swept before starting to pour the grain from the sack.
- The grain to be treated is poured into a heap on a clean floor, sheet or tarpaulin.
- The amount of insecticide dust needed to treat the heap of grain is put into the sprinkler. All the insecticide dust is sprinkled over the surface of the heap.
- The insecticide powder is mixed into the grain by shifting the heap from one spot to another using a clean shovel or hoe. Care must be taken to ensure that the dust is not blown away by the wind!
- This is repeated three or four times until the insecticide is properly mixed and no patches of powder can be seen.
- The treated grain is stored in clean bags, containers or stores.

Layering insecticide with grain in store
This method is suitable for treating grain while filling the store. It can also be used for treating maize cobs, sorghum or millet heads and pulses in pod.

- If maize cobs are not husked before storing, any cobs that have poor husk cover or show signs of damage should be removed
- The inside walls and floor of the store are sprinkled with a layer of insecticide powder.
- The grain (or cobs, pods or heads) are poured into the store and spread to a depth of about 10 cm.
- The insecticide powder is sprinkled evenly over the layer of grain.

FIGURE 8
Method A. Mixing insecticide with threshed grain

FIGURE 9
Method B. Mixing insecticide with threshed grain

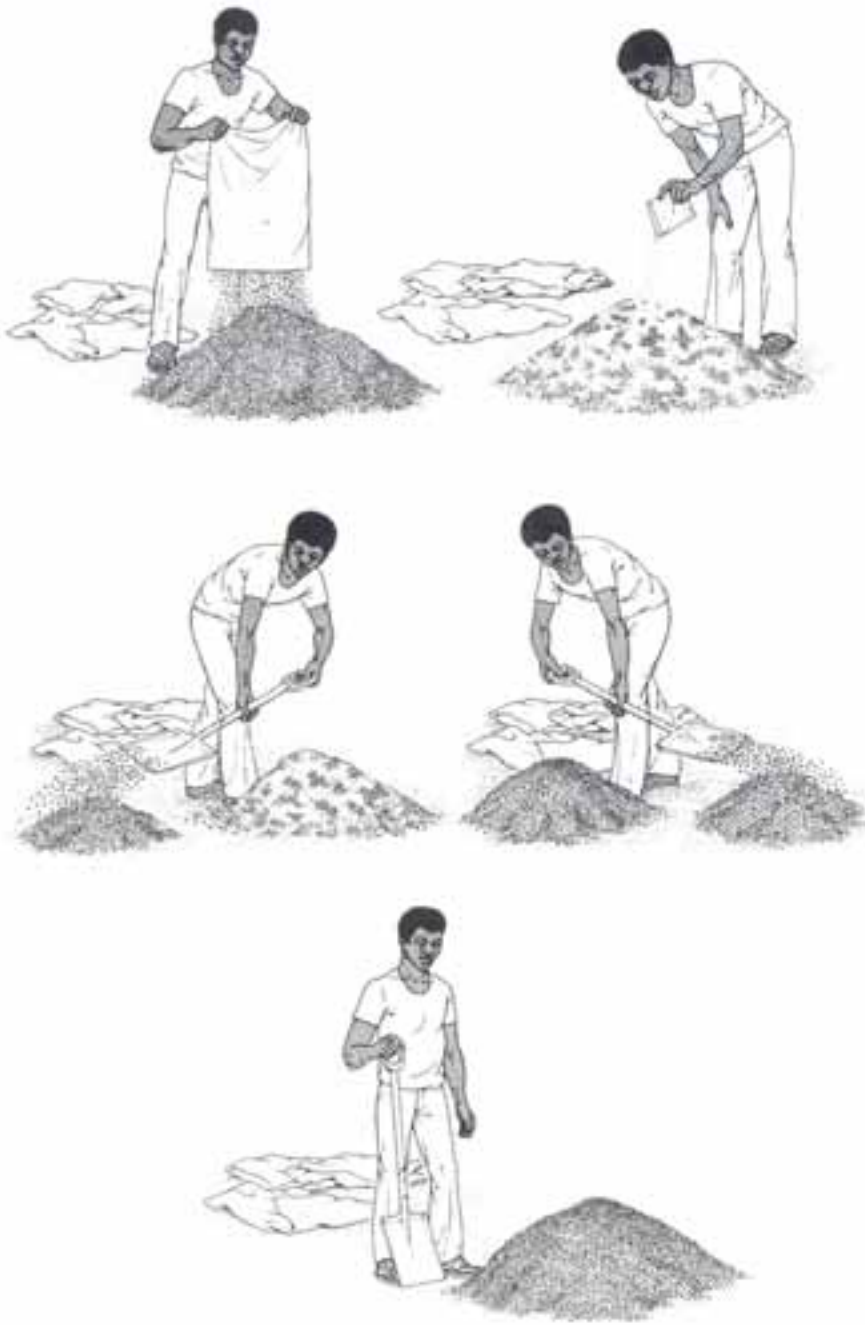
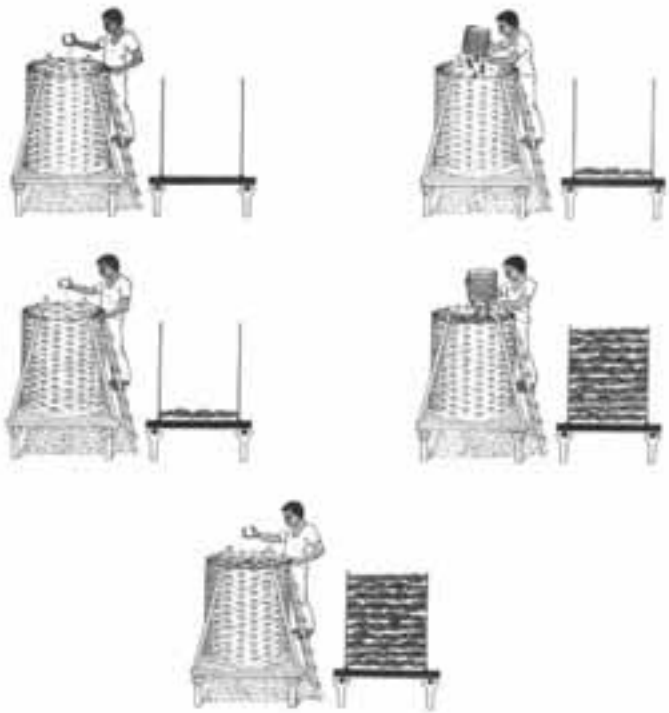


FIGURE 10
Layering insecticide with grain in store



- A second layer of grain about 10 cm deep is added. This second layer is sprinkled with insecticide as before.

- Further layers of grain are added and insecticide applied to each layer until the store is full or until all the grain has been treated. A layer of insecticide dust should be applied to the topmost layer of grain before the roof is put in place or the lid closed.

When treating cobs, three times the amount of insecticide dust used to treat the same volume of grain is required. Therefore, if 100 g of dust is recommended for application to one sack of grain (50 kg), 300 g of dust will be needed to treat one sack of cobs.

This makes treatment of cobs very expensive as one sack full of cobs contains only one-third of the grain (16-17 kg) to be found in a sack of shelled grain (50 kg). It is therefore six times as expensive to treat cobs effectively with dust insecticide.

How to apply liquid insecticides to maize stored on the cob

It may be necessary to treat maize cobs of high-yielding varieties with an insecticide when they are stored in cribs or baskets. Treatment is recommended if for any reason the maize cannot be shelled.

- The store should be cleaned and all old maize cobs, maize grains and rubbish removed.

- The amount of insecticide concentrate needed to treat the maize according to the manufacturer's recommendations must be calculated.

- The insecticide concentrate is mixed with the correct amount of water according to the manufacturer's recommendations. Gloves should be worn for this.

Plate 17
Spraying maize cobs with insecticide before storage

- The insecticide is put into a sprayer. Alternatively, a suitable applicator can be made using a container with a well fitting screw lid and small holes punched into the lid.

- The cobs to be treated are spread in a single layer on the ground. Any cobs that show signs of damage should be removed; only clean cobs should be stored.

- The insecticide is applied to the cobs using the sprayer or applicator.

- The insecticide should be applied to the inside of the store (crib or basket) before filling with treated cobs.

BOX 5

Working safely with insecticides

- When handling and mixing insecticide concentrate the liquid must not be spilled on the skin. If possible, rubber gloves should be worn.
- Smoking, drinking or eating is not permitted while applying insecticides.
- When the treatment is finished – hands and face should be washed with soap and plenty of water. This should also be done if any insecticide is spilt on the skin or splashed into eyes or on hair.
- Empty insecticide packets and containers must be disposed of carefully – preferably burnt or buried.
- Any unused insecticide should be stored in closed airtight containers in a cool dry place, away from treated grain and where children or domestic animals cannot reach it.

This method can also be used when cobs are dried and stored on a vertical frame. In this case, only a sprayer can be used. Half of the spray solution should be applied to cobs on one side of the frame and half to those on the other side. Care must be taken to ensure that all the cobs are treated; the frame must not be built so high that the spray cannot reach the upper layers of cobs. For safety, the sprayer should always stand on the ground when spraying and not on a ladder.

Fumigation

Fumigation kills insects inside grains with phosphine gas. Phosphine is released from aluminium phosphide tablets when these are exposed to air. *The gas is lethal even in low concentrations to humans and livestock*. Gas is released from the tablets within 20 minutes in some climates. **It is therefore essential that only trained personnel undertake fumigations. Untrained personnel must not handle the tablets.**

Fumigations are only effective if carried out in gas-tight enclosures. Traditional farmers' stores, even mud plastered or mud brick buildings, are not gas-tight and must not be used for fumigation. Leakage of gas is extremely dangerous for the farmer's family and animals and does not kill insects in the grain.

Small-scale fumigation can be carried out under gas-tight covers such as thick polythene sheets, or in containers that can be easily sealed, such as polypropylene water tanks or purpose-built metal tanks. Farmers producing many tonnes of grain can hire trained extension personnel or private pest control operators to fumigate their crops at the homestead as long as the area to be fumigated can be made gas-tight. Alternatively, farmers may be able to take their produce to a fumigation centre where it can be fumigated under controlled conditions by trained personnel who can guarantee that the grain will be free of insects after treatment.

A fumigation centre has been established at the main market for northern Ghana in Tamale. For a small fee to cover operating costs, farmers and market traders can have their grains fumigated by trained personnel from the Ministry of Agriculture. Sacks of grain may also be stored at the site. This can be a model for other countries to adopt.

A good fumigation, which lasts from seven to ten days, will kill all insects present but it will not provide long-lasting protection against infestation. It may be necessary to use the grain immediately or to treat it with insecticide to ensure that reinfestation does not occur.

Plate 18
Two different commercial containers with aluminium phosphide tablets

Plate 19
A fumigation under a thick polythene sheet carried out in a trader's store.

Plate 20
A rural fumigation under a gas-tight sheet held in place with loose soil. The soil helps to create a gas-tight seal between the sheet and the ground

Plate 21
Fumigation centre - Tamale market, northern Ghana

3.2 MOULDS

Moulds are growths that develop inside and on the surface of grains that have not been dried properly or become wet during storage. They can be recognized as white, grey, black or green discolouration on the grain surface. Other signs of the presence of mould are:

- dustiness of grain;
- caking of grain;
- feed refusal by animals for no apparent reason;
- a bad musty (mouldy) smell;
- darkening of feed grain.

Plate 22
Aspergillus ear rot

Grain spoilt by moulds is often thrown away, although in some instances it may be fed to livestock or used to brew beer. In times of food shortage people may resort to eating mouldy grain if they have no other source of food. However, it is not wise to eat mouldy grain because moulds produce poisonous substances called mycotoxins that can be hazardous to humans and livestock. Eating mouldy grain has led to severe illness and even to death in several countries. Poisoning can cause cancers and can affect most of the organs of the body but especially the stomach, kidneys, liver, and brain. Consumption of mouldy grain may also make illnesses such as HIV/AIDS worse.

Mouldy grain is difficult to sell when sufficient food is available and always fetches low prices.

Some moulds found on stored grain can actually attack the crop before it is brought from the field. It is very important, therefore, to make sure that grain is dried as quickly and as thoroughly as possible, once the growing crop has reached maturity.

Factors that affect mould growth

- Moisture content of the grain; moulds require water for growth, so if the crop is well dried (below 13% for cereals and 7% for groundnuts), moulds will not be able to grow.
- climatic conditions; hot and humid conditions promote mould growth. Under such conditions, extra attention must be paid to drying the crop well.
- field damage caused by insects, birds, rodents, and poultry (moulds can quickly infect grain through holes and cracks made by pests);
- plant stress caused by drought, infertile soil and even untimely or excessive fertilizer application (allows plants and seed to crack and become exposed to invading moulds and insects);
- maize cobs, sorghum and millet heads and pods of pulses that fall to the ground and come into contact with mould spores that live in the soil;
- repeated planting of a crop in the same field may increase the risk of infection by mould;
- poor handling at harvest, during drying, threshing and transportation can cause damage to grain, rendering it susceptible to attack by mould spores; and
- insect infestation in store (insect respiration produces water, which raises the moisture content of the grain allowing moulds to develop).

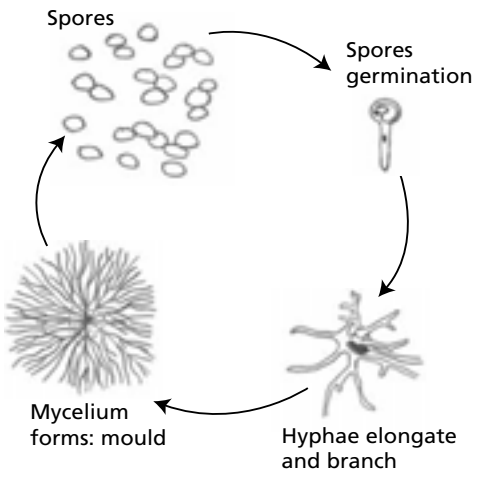
Which are the important moulds?

There are two important types of storage moulds, *Aspergillus* and *Penicillium*. Another common mould is *Fusarium*, which attacks the plant in the field but, if the moisture content of the grain remains high, may be carried over into the store after harvest. All of these moulds produce harmful mycotoxins.

Plate 23
Fusarium ear rot

Plate 24
Green mould - *Aspergillus mycelium*

FIGURE 11
Fungal life cycle (*Aspergillus*)



Source: adapted from Aspergillus Website, UK
http://www.aspergillus.org.uk

FIGURE 12
Weeding

Moulds multiply by releasing spherical spores. These germinate, producing elongated projections known as hyphae. Hyphae multiply and branch and form a mass of fungal tissue, the mycelium, at which stage it is recognizable as mould by its colour.

Prevention and control

The most effective way of preventing mould growth is to dry the grain as quickly as possible to a moisture content that is low enough for safe storage. Safe storage is achieved when moulds cannot develop. For cereals and pulses in tropical and subtropical countries this point is achieved when the moisture content is below 13-14 percent, for groundnuts and other oilseeds below 7 percent. Once the grain is dry it must be kept dry while in store.

Other control measures after drying

- Ensuring that grain saved as seed is healthy and free of pests and diseases. Healthy seed will produce vigorous plants that can better withstand invasion by diseases, including moulds.

- Avoiding drought stress either by using irrigation or by planting early to avoid rain failure towards the end of the growing season.

- Keeping the growing crop clean and free of weeds. This will prevent an old crop from becoming a reservoir for mould to infest the new crop.

- Practising crop rotation as much as possible. This will reduce the build-up of mould spores in the soil.

- Where possible, planting disease resistant varieties (however, there are no *Aspergillus*-resistant varieties).

- Avoiding nutrient stress by applying organic or inorganic fertilizer, but doing so at the appropriate time and with recommended quantities.

Field drying

When the growing crop has reached maturity it begins to dry. If left in the field it will eventually become dry enough to store. However, the longer it stays in the field the more likely it will become infested by storage insects, damaged by rodents and other animals, or be stolen. Therefore, it is best to transport the crop to the homestead as quickly as possible where it can be dried safely.

If it is not practical to transport the crop quickly, some drying will have to take place in the field. This can be done as follows:

- Simply leaving the plants standing in the field, although there is a risk that unexpected rains will cause re-wetting

- Bending over the maize cobs or heads of sorghum and millet to prevent moisture reaching them through the stem.

- Piling stalks with heads into standing heaps ('stooks') to allow cultivation of the field, although this may slow down the drying rate.

- Removing cobs, heads of grain or pods of pulses and piling them into a heap on a bed of straw or palm or banana fronds before threshing.

- Drying crops should never be placed directly on the ground as they may get wet or come into contact with moulds in the soil.

Sun drying

Grain can be dried by spreading it in thin layers in the sun. It should be stirred occasionally to ensure that all the grain is exposed to the sun. The grain should never be spread out directly on the ground because of the risk of drawing up moisture from the soil. Spreading grain across a concrete plinth will speed drying and will also reduce contamination from dirt. Better still, spreading grain on a polythene or cloth sheet, or empty sacks, enables it to be gathered quickly and protected from rain. A black polythene sheet will also help by absorbing heat from the sun and so speed up drying.

Plate 25
Maize stook, Kathmandu Valley, Nepal

Platforms and frames

Unthreshed cereals and pulses can be hung on a wooden frame or heaped on a platform to dry. A fire can be lit beneath the platform to increase the rate of drying. This fire can also be used for cooking. The platform could be located inside the house, under the roof eaves and above the kitchen fire, in which case the fire provides all the heat for drying.

Outside drying structures should be ideally one metre, but otherwise at least 0.75 m, above the ground and fitted with rodent baffles on the legs. Where termites are a concern the supporting poles of the platform and frame should be soaked in, or painted with, used engine oil.

Drying cribs

Drying platforms may be converted into dual function drying and storage cribs. These have walls made from wire netting, bamboo, sisal poles, sawn timber or similar materials, which allow the free flow of air but also protect the crop from driving rain. The roof must have a good overhang and be robust enough to prevent rain from penetrating. Maize cobs, sorghum or millet heads and legumes in shell dry best in narrow cribs, which should be ideally between 0.5 m and 1.5 m wide, and erected in the open with the long sides across

Plates 26 and 27
Maize cobs tied on frame and stored on platform to dry

Plate 28
Typical African crib

Plate 29
Solar dryer

the prevailing wind to allow for a good flow of air through the crop. A fire can also be lit under these structures.

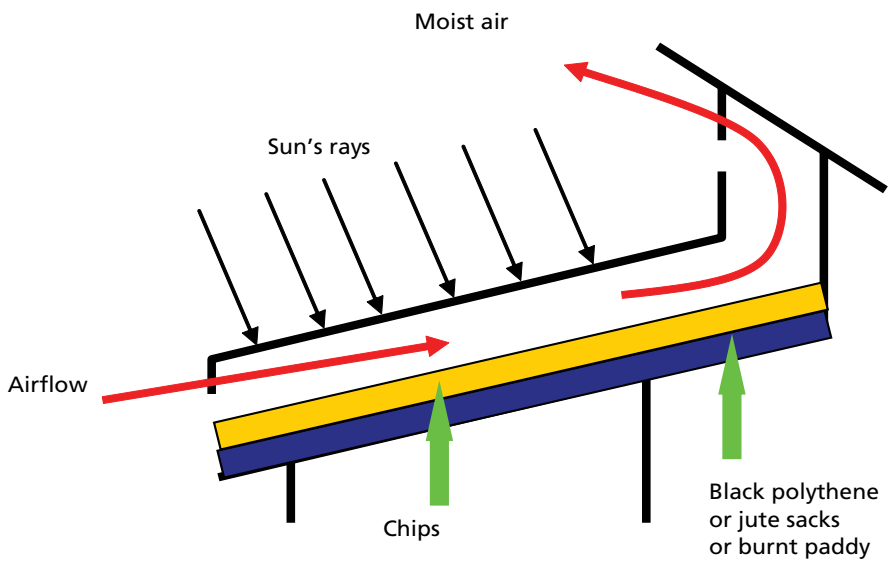
Solar dryers

In areas of high humidity or prolonged rainfall, natural drying as described above might not be fast enough to prevent moulds developing. A purpose-built solar dryer will increase the rate of post-harvest drying. Solar dryers collect the sun's heat inside a specially designed chamber that has adequate ventilation for removal of moist air. These can be relatively cheap and simple to construct and are appropriate for use by individuals or small groups of farmers.

Estimating moisture content of grain

The accurate measurement of grain moisture content requires equipment that is beyond the reach of most small-scale farmers. However, moisture can be estimated using a simple and inexpensive method called the "salt test". Dry common salt (non-iodized) is mixed with the grain sample in a glass jar and shaken. The equilibrium relative humidity of dry salt is 75 percent at ambient temperature. The moisture content of grain at 75 percent relative humidity is about 15 percent (wet weight basis). So, if the salt in the grain sample adheres to the walls of the glass, it has absorbed moisture from the air which must therefore be at a relative humidity greater than 75 percent. This means that the grain has a moisture content greater than 15 percent and is unsuitable for storage.

FIGURE 13
Cross section through a solar dryer



3.3 TERMITES

Termites are not usually regarded as storage pests. However, despite the fact that they do not generally attack grain directly (unless the commodity is in their path), they will damage and destroy the structures in which the grain is stored. Stores made from wood, timber or bamboo and those constructed using mud are all at risk from termite damage. Damage can become so severe that the entire structure may collapse, leaving the crop open to attack by termites, storage insects and rodents, and vulnerable to theft.

Three different types of termites live in each colony.

- *Reproductives* - at least one pair, male (king) and female (queen), in each colony; the abdomen of the queen becomes very large, filled with ovaries, and eggs are laid continuously throughout life. *Alates* are winged reproductives that fly after the rains and, after pairing, form a new colony.

- *Workers* - have many different jobs including building and maintaining the nest, tending the young and foraging for food; it is the worker termites that cause damage to stores.

- *Soldiers* - defend the nest, guarding the reproductives and workers from predators; they have large jaws or mandibles, which are distinctly shaped and can be used for species identification.

Termite colonies may be seen as large or small mounds. They may be entirely underground or nests may be found on the ground surface or in trees or even inside tree branches. Each family of termites can be identified by the type of nest it occupies.

Termite species are often difficult to identify, however, the shape and size of the mandibles of the soldiers are sometimes used in identification.

It is important for farmers to ensure that termites do not attack their store. There are three ways in which termite problems can be tackled.

First, termite nests can be destroyed; however, this is not easy to achieve because the termites may be coming from a nest that is underground and therefore difficult to locate, or the mound may be some distance away.

Plate 30
Maize cobs damaged by termites

Plate 31
Queen, king, soldier and worker termites

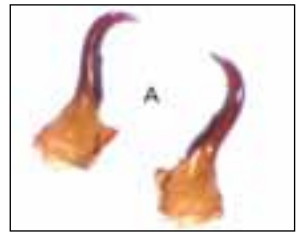
© C.VIEZZOLI

© M.POUDYAL

Plates 32 and 33
Termite mounds

FIGURE 14
Life cycle of termites

Source: Howstuffworks.com



PHOTOS: © M.MESSENGER

Plates 34, 35 and 36
Mandibles of soldier termites: (A) Microtermes (B) Odontotermes and (C) Amitermes

Second, the store can be protected by applying a poisonous termiticide to the structure. These chemicals are generally very toxic if they are to be effective and therefore must not be allowed to come into contact with grains.

Third, termites must be prevented from coming into contact with the store. In order to achieve this goal:

- any store built outside the house must be easy to inspect so that the earliest signs of termite activity can be detected;
- the ground around the store must be clean, free of plants and debris;
- the storage structure should be at least 1 m from the nearest tree or other building;
- stores with support legs made of compacted mud should rest on a concrete block or large stone to help deter the access of termites; and
- wooden support poles should be treated by dipping in used engine oil, or by painting or spraying with a proprietary insecticide, such as Bendiocarb.

3.4 RODENTS

Rats and mice damage storage containers, eat some of the stored produce, carry some away to their nests and spoil much more with droppings, urine and hairs. They usually spoil more than they actually eat. They chew through bags allowing produce to spill out. It is important to remember that rodents are also carriers of disease, including plague, rat-bite fever, and Lassa fever.

Rodents are very good climbers, they can swim and can jump very effectively. They can easily gain access to most traditional grain stores because the materials used for store construction provide little or no barrier. Rodents can chew holes in baskets and woodwork of stores and burrow through mud floors and walls to get at stored produce.

Only stores constructed from metal, brick or concrete are likely to protect stored produce against rodents.

Rodent control

The most effective method of preventing rodent damage is to keep the store clean and tidy and to have rodent proofing in place.

Rats and mice will stay in a store only if they can get food easily and find somewhere to make a nest. The area around the store must be kept clean. All spilt grain, rubbish, empty sacks and household items that may harbour rodents should be removed.

Rat guards should be attached to the legs and supports of grain stores. The rat guard must be at least 1 m above ground level; otherwise the rodents might be able to jump over it. All of the supports must be fitted with guards. Stores should be built at least 1 m away from trees, poles or buildings.

Traps should be used inside the house or storeroom. Break-back traps with a treadle are the best type and should be laid across rodent runs. Rodents usually move round the

Plate 37
Store supported on termite proof plinth surrounds is very easy to inspect

Plate 38
Rat being enticed to a break-back trap by loose groundnuts

Plates 39 and 40
Rat climbing

base of the walls of a room, so traps should be placed on the floor by the walls or in the corners. Rats are suspicious of new objects and so the traps should be left unset for a few days until the rats are running freely over them. Traps for mice can be baited and set immediately.

Poisoning of rodents with rodenticides is not recommended at the small-farm level. Although the rodenticides kill rodents, more may soon arrive from elsewhere as long as the food source remains available. Many rodent poisons are dangerous chemicals and are a potential health hazard to humans and animals unless used by a person with special training in rat control.

Plate 41
Store with metal rat guards fixed to legs and supports

Keeping the compounds and surroundings in the village free from rubbish eliminates breeding sites for rodents and is the most practical solution for rodent control.

3.5 BIRDS

Some species of birds commonly feed on stored grain. Birds can consume large amounts of grain. They also contaminate the grain with their droppings and feathers.

Damage and loss of stored grain can be reduced by preventing birds from entering the store. The store should be kept in good condition and the entrance or door to the store kept closed.

The area around the store and compound should be kept clean as birds are attracted by spilled grain.

Chapter 4
Storage methods

Traditional methods of storage have evolved over long periods and many generations and are usually well suited to the climatic and social environment in which they are used. The traditional system has achieved a balance whereby relatively small quantities of grain can be stored over many months, with little damage, and be sufficient to meet immediate family needs. Although pests may be present, they are usually held in check by the following: the nature of the commodity stored (for example, maize with tight husks); adverse weather conditions (particularly long dry spells); relatively short storage (usually up to about six months); and the use of traditional insecticides. Problems for farmers begin when changes to the system are introduced or needed, such as:

- cultivation of improved varieties;
- desire to increase production and extend the storage period;
- need for alternative building materials when there are shortages of traditional materials, such as grass for roof thatch and bamboo for baskets;
- availability of improved building materials, such as galvanized roofing sheets;
- availability of synthetic pesticides;
- using mechanical handling methods for harvest and threshing;
- introduction of new pests, such as the larger grain borer, a pest of stored maize introduced to Africa less than 30 years ago;
- loss of traditional building skills, for example, when people move away from their traditional home; and
- demand by consumers for high quality produce.

Farmers may need to look for alternative or improved types of storage structures to either replace or improve their traditional stores.

Improved storage structures include both modifications to traditional systems and the introduction of new store types. They incorporate or are made entirely from industrially produced materials, such as prepared timber, cement and galvanized iron sheets. Farmers may have difficulty in accepting improvements unless they can see the benefits for

Plates 42, 43 and 44
A selection of containers used for storing seed grain

themselves and are able to afford them. The individual farmer's level of production and need for storage will influence his or her willingness or ability to change and the type of store that may be adopted.

4.1 SEED STORAGE

Many farmers retain their own seed each year. Soon after harvest, seed grain is selected from the crop that has just been brought home. Usually, the seed is of the best visible quality and farmers try to take good care of it while in store. Generally, relatively small quantities are kept back and these cannot be kept in the stores normally reserved for food grain. Any reduction in the quality of seed, such as insect and mould damage and shrivelling through water loss or heat exposure, will reduce the germination potential and therefore reduce the size of the next crop. Seed storage therefore demands extra careful management.

Containers for storage of seed should be sealable and just large enough for the quantity to be stored. The grain must be dry and free of insect pests. If seed is stored in an airtight (hermetic) container, such as in a bottle with a tight fitting lid, insects in the grain will die from the combined effects of reduced levels of oxygen and poisoning by the accumulated carbon dioxide produced as they respire.

Grain may be stored in sealed pots or gourds, or in tins or bottles. The grain must be dry; otherwise it will go mouldy or ferment, as these containers do not allow water to be lost to the outside. These methods are fine for keeping grain free from pests as long as the container is well sealed. Plastic water containers with screw-on lids make ideal seed stores.

Larger quantities of maize seed are frequently stored by suspending entire cobs from the roof eaves or overhang of the house; they may also be suspended

Plate 45
Seed grain under the eaves of the house

Plate 46
Storage platform, Southern Africa

Plate 47
West African cone-shaped maize store

from trees. Cobs may escape the ravages of rodents and birds but they are susceptible to insect pests.

4.2 FOOD GRAIN STORAGE

The commonly used methods for storing grains are described below. These structures can hold up to two tonnes, though some may hold much more.

Platforms and frames

Platforms constructed in the open may be four-cornered or circular racks made from timber, bamboo or sisal poles. They are usually raised on legs about 1.5 m above the ground. Cereals and pulses are stored unthreshed in heaps or in regular stacks. As the commodity may be placed on the platform very soon after harvest, the structure can be regarded as a drying and storage system. A fire, often the cooking fire, may be lit underneath the platform to speed up drying and to deter pests. The platforms may be completely covered with a detachable thatch roof, which can be lifted off from time to time to aid drying or to remove produce.

In humid areas, maize cobs in husk may be stacked in layers to form a cylindrical stack, which is then covered by a cone-shaped roof. Instead of being flat, the platform may be cone-shaped with the point at the base. These structures may assist drying. Other variants of the flat platform include those constructed inside the house, often over the cooking fire, and as a storage loft in the roof of the house.

Frames consisting of narrow timber or bamboo poles fixed horizontally to heavy upright poles embedded in the ground can be used for holding maize cobs during drying. Cobs are tied in pairs by the outer husk leaves and each pair is then slung across the frame.

Platforms and frames can be made at minimal cost from local materials. Improvements to platforms in the open are limited to the fixing of rodent guards to the legs.

It is easy to load and empty platforms and frames; however, skilled stackers may be required when maize cobs are stacked in layers on platforms.

Platforms and frames provide no protection against theft.

Plate 48
Maize cobs stored on frames

Plate 49
West African maize crib

Drying and storage cribs

Traditional cribs are circular or rectangular with a framework of wooden poles.

Ideally, the width of the crib should not exceed:

- 0.6 m in humid areas where maize is harvested at high moisture content (30-35 percent);
- 1.0 m in dryer zones with a single rainy season where maize is harvested with about 25 percent moisture content;
- 1.5 m in very dry places.

It should be erected in the open, with the long side across the prevailing wind. This will ensure good ventilation and drying. Grain dries better in a narrow crib.

Walls can be made from raffia, bamboo, sisal poles, sawn timber or wire netting. At least half of the wall area should be open to ensure good ventilation. Roofs can be of thatch or corrugated iron sheets. The floor of the crib should be at least 1 m above ground level and legs should be fitted with rodent guards.

Cribs are primarily intended for drying produce, especially maize on the cob. If they are to be used for storage after drying is complete, it may be necessary to cover the walls with mats to protect the grain from driving rain.

Traditional cribs can be made at minimal cost when local materials are readily available. Improvements can be made using both traditional and non-traditional materials. The cost of cribs will increase if materials have to be bought and if a builder is employed.

Cribs provide flexibility in use. They can be used for drying and storing unthreshed cereals and pulses and also for storing shelled grain in sacks. They can be modified easily for storing other commodities such as root crops.

Cribs can be used to hold early harvested maize cobs so that the field can be cleared quickly for land preparation for the next planting.

The open structure allows for easy cleaning and for periodic inspection of grain quality. Loading and emptying is relatively easy through the open framework or through a door.

Segregation of several different lots of grain is not very practicable (although it may be possible to fit one or two partitions).

Traditional cribs usually require a high level of maintenance and may have to be replaced completely after two to three years. Improved cribs made with sawn timber and with metal roof sheets may last for about ten years. Improved cribs made of local materials will not last as long. Maintenance costs will be higher as sawn timbers may have to be renewed and thatch replaced.

Stored grain is on display in a crib and thus reveals the size of the farmer's harvest. It may be difficult to protect against theft.

Cribs may be attractive to farmers wishing to hold damp grain on the farm for longer periods. However, their adoption may be constrained by shortage of local wood and thatch.

It will usually be necessary to treat the stored grain, especially maize cobs of high-yielding varieties, with an insecticide at the time of storing. Produce should be inspected regularly. If insects are seen the grain should be threshed or shelled as quickly as possible and mixed with an approved insecticide, and then stored in bags or other containers.

Baskets

Baskets with an open weave are suitable for drying grain, e.g. sorghum heads and maize cobs, especially without husks. Dry, shelled grain can be stored in close-weave baskets or baskets that have mudded walls.

Baskets may be woven from twigs, split bamboo, twisted grass rope and sorghum stalks. They may have tight-fitting lids and some may have additional loading or unloading hatches. Baskets may be used for drying and storage. They can be used without mud plaster for the drying phase and then plastered for the storage period.

A mud layer applied to the outer and inner walls of basket stores will provide protection from rain, strengthen the structure and restrict uptake of moisture by dry grain. It may also prevent damage to the basket by wood- boring beetles and restrict the rate of breakdown of insecticide dust by reducing airflow through the grain.

Mudded stores may be more secure, limiting access to the grain by small animals, such as goats and sheep, and reducing the potential for theft.

Basket stores can be kept inside the house or outside in the open. They should be raised off the ground, placed on stones or brick foundations or on a wooden platform to prevent uptake of ground moisture. If they are kept outside they should be placed under a shelter or have an extended thatched roof to provide protection against rain and shade from the sun.

Traditional basket stores are built in different shapes and sizes. Small baskets are easily portable. All basket stores are suitable for storage of both unthreshed and threshed cereals and pulses.

The material costs will be low for baskets made entirely from local materials. Village specialists may be

Plate 50
Traditional Ethiopian basket stores

Plates 51 and 52
Wicker and woven mat basket stores

Plate 53
Basket store with mudded walls

Plate 54
Solid wall bin

employed to make basket stores and they may charge for their skills.

Grain will keep satisfactorily as long as the basket is well maintained and steps are taken to control insects and to exclude rodents, e.g. fitting rodent guards to supporting legs. Mud plastered baskets with sealed lids may deter entry by insects, but grain that is vulnerable to insect attack, especially improved high-yielding varieties, may need to be protected with insecticide.

Baskets that are well made and maintained may have a life of up to 15 years. Maintenance will include: mending holes or splits in the basket weaving, repairing cracks in plastered walls and repairing or replacing thatched roofs. A mudded basket kept outside will need replastering annually. A cement plaster may last for several seasons.

Before loading, baskets should be cleaned thoroughly and insecticide dust should be sprinkled inside if insect infestation is expected.

Solid wall bins

Solid wall bins may be spherical, cylindrical or rectangular in shape. Designs are often characteristic of communities or localities. The bins may be made of clay (sometimes strengthened by mixing with straw or twigs) or clay blocks or burnt bricks. More affluent farmers may use bins made from concrete.

Bins are either raised off the ground or isolated from it by means of wooden poles, clay pedestals or large stones. Packed earth should not be used as the base because it may permit termites, rodents and ground moisture to enter the store.

Improved solid wall bins made of stones or bricks and mortar may have a concrete pedestal or foundation. A plastic sheet or tar paper may be used in the base to prevent uptake of moisture.

Plate 55
Solid wall bin

Thin-walled structures are commonly used for the storage of unthreshed pulses, sorghum, millet and maize cobs. Stronger, thick-walled structures are more suitable for storage of threshed grain.

Some bins have internal dividing walls making several compartments. This gives some flexibility in the different quantities or types of grain that can be stored. Separate openings for filling and emptying are usually included at the top and bottom of the structure. Covers for these openings can be secured with padlocks.

Costs increase in proportion to the amount of non-traditional material used in construction. Traditional solid wall bins may be constructed by skilled artisans who may charge for their skills.

The life of solid wall bins will depend on construction and local climatic conditions. With good routine maintenance and careful use a bin may last for more than 20 years. Solid wall bins are strong and their contents are not displayed to prospective thieves. Their durability and security may make solid wall bins attractive to small-scale farmers wishing to store grain for longer periods at a relatively low cost.

The quality of grain stored in solid wall bins may be affected by climate and insect pest infestation as well as the standard of design and construction of the bin. All bins using mud in their construction are susceptible to termite attack. Insect infestation in grain may be readily controlled using insecticide dusts. However, these stores are not airtight and cannot be fumigated.

The area around the bin must be kept clean and the bin should be thoroughly swept clean at the end of each storage season. Smoke from a small grass fire lit inside the empty bin will kill insects. Cracks in plaster should be repaired quickly.

Metal storage bins

Metal storage bins are made from smooth or corrugated galvanized metal sheets. They are usually cylindrical in shape with a flat top and bottom. Most bins used for small-scale storage have a capacity of up to 1 tonne. Grain is loaded through a hatch in the top and can be emptied through a spout in the side at the bottom of the bin.

Metal bins can provide maximum protection and security when padlocks are fitted to the filling hatch and emptying spout.

Plates 56 and 57
Metal storage bins in Malawi (left) and Bolivia (right)

Metal bins should be placed on platforms or legs to allow air to circulate around the base in order to prevent corrosion from ground moisture. They should be placed under a roof to provide shade and to help reduce moisture migration and heating of the grain inside.

The costs of bins vary with the size, the charges made by skilled metal workers, and the distance they have to be transported from manufacturer to farmer. Although bins can be constructed in different sizes (capacities) the cost per tonne of small units may be prohibitive for small-scale farmers.

The use of metal grain bins by smallholder farmers is fairly restricted. In Africa, they are relatively common in Namibia and Swaziland. Outside Africa, metal grain bins are found in Central America (Nicaragua, Guatemala and Honduras) and on the Indian subcontinent. Where there are local craftsman working in metal to produce water tanks there is potential for their conversion to grain stores.

Large metal bins are more difficult and expensive to transport to rural areas and are easily damaged in transit over rural roads. Facilities for construction of large bins on site are rare.

As grain must be very dry for storage in metal bins, the system is more suited to areas where drying facilities are available or where the crop is harvested and stored in a distinct long dry season. With routine maintenance and careful use, metal grain bins can remain serviceable for more than 20 years. Maintenance includes cleaning out residues at the beginning of every season, protecting against corrosion and ensuring that the roof shelter is kept in good repair.

A well made and well sealed metal bin will provide good protection against insects, mould, rodents and birds. Insect control using insecticides or fumigation is essential.

Before storage, grain must be very well dried, threshed or shelled and then sieved or winnowed. Grain stored in metal bins should be drier than that stored in traditional stores that are well ventilated (e.g. baskets) or bags.

Underground storage

Pit stores are used in some parts of Africa, the Middle East and Southern Asia, primarily for storage of sorghum, millet and small grain pulses such as gram. The best pit stores provide a reliable, hermetic method of long-term storage.

Plate 58
Opening of underground pit store

Farm-level pit stores may have capacities ranging from 0.5 tonnes to more than 20 tonnes. Pits may be straight-sided, circular or square and some are constructed in the shape of a flask. Pits must always be dug above the water table.

An absorbent pit lining made from grass matting and straw or chaff and grain husks will help to reduce damage from moisture that might seep through the walls of the pit. The lining may need replacing every year. Alternatively, pits may be lined with plastic sheeting.

A fire can be lit inside the empty pit to aid drying and to kill micro-organisms and insects.

Filling pit stores is easy but emptying and routine inspections are not.

Pit storage is popular because the entire store can be completely concealed underground and the grain is unlikely to be stolen. There is no risk of damage by fire.

Well sealed pits will prevent entry by insects. Some initial mould growth in filled pits is likely, but this may reduce oxygen levels, which in turn can asphyxiate insects and inhibit further mould growth.

Grain stored in pits often has a characteristic smell and taste associated with the development of moulds.

Grain stored in pits is sometimes damaged by termites. Occasionally burrowing rodents may gain access to the stored grain.

Bag storage

Bag storage is a convenient way of keeping threshed grain and pulses. The need to thresh or shell grain may deter farmers from using bags if labour is in short supply at harvest time. These difficulties may be overcome by the use of shellers or threshers.

Bags are usually made from jute or woven polypropylene, but hemp, sisal, grass and polythene sacks are also available. Sometimes plastic bags (old fertilizer bags) may be used for the storage of grain. Durability of bags will depend on their quality and how they are handled. Jute sacks are more expensive but last longer than woven polypropylene ones, which are liable to degrade in sunlight. With careful use and repair, bags should last for several seasons.

Bags provide the flexibility to store different types and different quantities of cereals and pulses. The storage capacity is limited only by the number of bags available and the size of the storeroom. Small numbers of bags may be kept in the farmer's house or in a separate store. This might include a room attached to the house, a simple pole and thatch shelter or a separate building made from traditional or non-traditional materials (bricks and cement). Bags of grain may also be stored in maize cribs. Ideally, one room or store should be kept for use entirely as a grain store.

It is important that bags of grain are never placed directly on the floor. They should be stored on small storage platforms made from wooden poles (dunnage). This will allow air to flow under the stacks and will stop the bags getting wet from the uptake of moisture from the ground. If no wood is available the bags should be stacked on a plastic sheet.

Plate 59
Bags stored on dunnage

The area around the stack should be kept clear of household items that might provide hiding places for insects and rodents.

The stack should be well constructed to prevent collapse and kept away from the walls of the store if possible. In the house the stack should be kept away from the kitchen and fireplace.

Bag storage is a convenient way of handling and storing grain and pulses. The commodity can easily be removed for consumption, inspection or sun drying and is immediately available for sale.

Bags can be easily carried away. Those stored in a farmer's house or shed are fairly secure, especially if doors are locked and windows barred. Bags stored in maize cribs are less secure.

The initial cost to make a storage space for a few bags is low. Costs of building a separate secure storeroom may be high, but the store could have other uses. There will be recurring costs of sacks and insecticide for treatment of grain.

Successful bag storage depends on the adoption of good storage management rather than the construction and operation of a special storage structure. Bags provide little protection against insects, rodents and moisture. If the risk of insect attack is high, the grain must be treated with an appropriate insecticide dust. Sacks should be brushed clean and dipped in boiling water to kill any insects present at the start of each season.

Damage to sacks and contamination by rodents can be a problem and risk of grain loss is high unless preventive measures are taken.

Damage by moisture can be prevented by keeping bags off the floor and by maintaining a sound roof over the stored bags.

Miscellaneous containers

There are other containers used for storage of grain that do not fit into any of the above categories.

Metal drums, for example the widely used 44 litre capacity drums, may make convenient grain storage bins. These drums rarely have a lid. Nevertheless, by stretching a sheet of polythene over the top opening and fastening it securely with, for example, a rubber band cut from a tyre inner tube, the drum can be made airtight. Drums are useful for storing grain and unthreshed commodities, especially when the farmer produces small amounts or a variety of different crops and a different drum can be reserved for each crop.

In some areas of western Tanzania, farmers store small quantities of maize, sometimes for seed, in cylindrical containers made from the bark of local trees. This drum, known

locally as a *kilindo*, varies in size from 0.5 m in height with a diameter of 0.25 m to some made from several pieces of bark that are up to 2 m high with a diameter of 2 m.

People are very inventive when it comes to making the best use of the materials that are available to them. For example, Plate 62 shows a store for maize cobs, which has been made from the body of an old car with a grass infill. It is, of course, at risk of being damaged by rodents and insects as well as small domestic livestock and perhaps neighbours.

Many farm families try to keep their entire stored crop inside the house to avoid theft. Grain is usually stored in sacks in the house, but unthreshed crops are stored in small solid wall bins, baskets, on platforms or simply piled in heaps on the floor. Others store crops in the roof eaves on a platform or leave them suspended from the wooden roof cross members.

Plate 60
Metal drums

Plate 61
Seed grain container made from tree bark

Plate 62
Unusual maize store construction utilizing the shell of an old car

Plate 63
Maize cobs stored in roof space of house

Chapter 5
Good storage practice

If grain is to remain in good condition from harvest to the time that it is to be consumed or sold, the farmer must follow the four pillars of good storage practice. This means:

- ensuring that the crop going into store is in good condition;
- keeping the store in good condition;
- practising good store hygiene; and
- maintaining the condition of crop and store throughout the storage season.

5.1 ENSURING THAT THE CROP GOING INTO STORE IS IN GOOD CONDITION

Good quality whole grain is less likely to suffer insect attack than poor quality damaged grain.

The grain should be checked after maturity while the crop is still standing in the field and immediately before harvest. Grain that shows signs of infestation or damage should be separated out before harvest and either discarded, reserved for animal feed or, depending on the type and extent of damage, kept for immediate consumption.

The grain should be cleaned well and any damaged grain removed. Careful winnowing will remove many live adult insects. Straw, chaff, weed seeds, stones and dirt must be removed. These materials will hold water and their removal will allow grain to dry faster. Any rubbish should be burnt.

The grain should be well dried. Good drying is essential. Damp grain will become mouldy. Insects are less likely to attack well dried grain. If the crop is to be dried in the field, it should not be heaped directly on the ground in order to prevent moisture being taken up. Similarly, when grain is dried at the homestead it must be kept off the soil.

Threshed grain can be dried on polythene sheeting, grass matting or sacks placed on the ground in the sun. Unthreshed crops, (cobs, heads and pods) can be dried in the same way although it is better to dry them on platforms or frames or in cribs. Solar dryers can be used for grain if these are available in the village.

Sun drying will help get rid of adult insects in the grain. Weevils will walk away from grain spread in the sun or will be killed if the grain gets hot quickly.

Sun drying will not kill all immature stages, like larvae, which live inside the grains. If adults have been found, it may be necessary to treat the grain with an insecticide, which will kill the immature stages once they mature and emerge from the grain as adults.

The crop should be carefully handled once it has dried to ensure that grain remains intact. This will restrict problems from secondary insect pests and moulds. In some places, farmers shell or thresh grain by placing it in a sack and beating it with sticks. Although this may be quick, the process does result in a high proportion of broken grains that will be susceptible to insect attack and mould infection.

Plates 64, 65 and 66
A selection of maize shelling devices

Maize is often shelled by hand. This produces better quality grain but is a very slow process. Quicker and effective shelling can be achieved using a variety of hand-held gadgets or pedal-operated machines. For these to work effectively, the grain must be sufficiently dry for safe storage; wet grain is difficult to shell. Although these devices make shelling more efficient, they are relatively scarce in farming communities.

5.2 KEEPING THE STORE IN GOOD CONDITION

A good store will keep the grain dry and cool. It should provide protection against rodents, birds and browsing domestic animals and poultry. It should be theft proof.

Stores should be sited in areas that are not prone to flooding; the soil should allow water to drain away readily. They should not be placed where high winds might damage the structure or near trees, which might provide access points from which rodents can jump onto the store roof or platform.

The store should have a roof to keep rain off the structure and to provide shade during the heat of the day. Without shade, the changes in temperature inside the store between day and night may be so great that as the store cools at night condensation occurs and wets the grain, which in turn may lead to the development of moulds. This is particularly important for metal grain bins.

To prevent groundwater soaking into the store, the structure must be raised off the ground. Mud silos and bins need only be supported on rocks or stones to create a small air gap. Unplastered structures should be raised at least 1 m above the ground to prevent rodent entry; they should be fitted with rat guards.

Most types of stores, apart from sealed mud silos, polyethylene and metal tanks, do not provide protection against insect entry; therefore they must be treated with insecticide.

The commonly available storage insecticides will also protect woven baskets against damage by the bamboo beetle *(Dinoderus)* and other wood-boring beetles.

The store must be kept in good repair to stop the roof leaking or the sides collapsing. A door should be fitted in the wall of the structure for access to the grain. A door eliminates the need to keep removing the store roof to gain access.

At the beginning of the new storage season the empty store must be cleaned. Residues of old grain and other rubbish must be removed and burnt. The roof and walls must be inspected and repaired where necessary; a thatched roof may need only some small repairs but most will need to be replaced every year.

5.3 PRACTISING GOOD STORE HYGIENE

This means keeping everything as clean as is practically possible.

The store surroundings should be tidied so that there is no vegetation or rubbish to hinder inspection or to provide breeding grounds for insects and rodents. Clearing the ground around the store will make it easy to spot termite trails.

Livestock should be kept away from the store; they should not be allowed to browse or sleep under the store; droppings should be cleared up as they attract rodents.

Whenever the storage containers are empty they should be cleaned. Secondhand sacks should be dipped into boiling water to kill any insects and then dried in the sun.

Grain residues should be removed from sacks by turning them inside out and thoroughly brushing them. Holes should be stitched.

Grass should be burnt inside solid walled bins and mud plastered baskets to kill off insects and mould spores. It is good practice to sprinkle the inside walls and floor of the structure with insecticide to kill any remaining insect pests.

Old grain should be stored separately from the new crop and it should be used first.

5.4 MAINTAINING THE CONDITION OF THE CROP AND THE STORE THROUGHOUT THE STORAGE SEASON

Pests can attack the store at any time so it is important to inspect the store and crop regularly. The earlier a problem is spotted the sooner action can be taken to control it so that less damage is done. Early action will prevent damage becoming severe.

If insect pests are a regular occurrence the grain should be treated with insecticide as soon as possible. Maize cobs can be sprayed with insecticide but it is more effective to shell the cobs and mix the grain with insecticide dust. It is particularly important to shell and treat pulses, especially beans and cowpeas, which become infested very quickly.

Store inspections should start as soon as the grain is put in store and then conducted routinely at weekly intervals. This is because insects may be brought in with the crop, which may have become infested in the field during harvesting or drying, or the store itself may have harboured an infestation from the previous season.

Even if the crop is insect free at the start of storage, regular inspection is necessary to spot insects that might fly in from a neighbour's store, trees and vegetation, or from grain purchased from the market. It is important to remember that maize insect pests will also attack sorghum, millet, dried cassava, dried sweet potatoes, rice and wheat.

During inspection, insect adults and signs of their presence should be looked for, such as holes in the grain, moth webbing, and large amounts of dust in the grain, on maize cobs,

on the outside surfaces of bags and under the store.

If infestations are seen, action must be taken as soon as possible. This usually means treating the grain with insecticide but it may be possible to sell untreated grain for immediate use if the damage is light.

For maize cobs – cobs should be shelled and the grain treated with an approved insecticide dust. It is not sufficient to treat the cobs because by this time the infestation will be present inside the grain and immune from a spray treatment.

As cobs are taken from the store, those that are heavily damaged should be separated for immediate use or disposal. Unwanted cobs and damaged grain that cannot be used for brewing or livestock feed should be burnt.

Infested pulses in pods and heads of cereals should likewise be threshed and the grain treated with insecticide unless it is to be consumed quickly.

For shelled grain and pulses stored in bags, baskets or bins – the grain should be removed from store and adult insects removed by sun drying or sieving and winnowing the grain. Dust and insects are then swept up and burnt. If the grain is not going to be used immediately, it should be mixed with an approved insecticide before storing again. The bags, baskets or bins should be cleaned before putting the grain back.

Signs of mould damage also need to be looked for. If maize cobs become mouldy, they should be removed and dried in the sun. Grain stored in bags can be checked by its smell. If the grain is going mouldy it will have a bad smell. The grain should be spread in the sun to dry and then stored in clean dry bags.

The store should be quickly repaired if it becomes damaged. If repairs are delayed a lot of grain may be lost to rats, mice and birds.

Good storage practice is the key to maintaining grain quality. Observing the four pillars described above will help farmers maintain the quality and value of their grain throughout the storage season.

Bibliography

Boxall, R., Golob, P. & Taylor, R. 1997. *Pest management in farm granaries*. Chatham, UK, Natural Resources Institute, University of Greenwich.

Brice, J. & Golob, P. 1998. *Fumigation of grain in farmer-level mud stores and metal grain tanks using phosphine. In* Jin Zuxum, Liang Quan, Liang Yongshen, Tan Xianchang & Guan Lainghua, eds. Proceedings of the 7th International Working Conference on Stored Product Protection, Beijing, China

Cobbinah, J.R., Moss, C., Golob, P. & Belmain, S.R. 1999. Conducting ethnobotanical surveys, an example from Ghana on plants used for the protection of stored cereals and pulses. *NRI Bulletin*, 77. Chatham, UK, Natural Resources Institute, University of Greenwich.

FAO. 2007. *On-farm mycotoxin control in food and feed grain*, by P. Golob. Good Practices for Animal Feed and Livestock Series No. 1, Rome, FAO.

FAO. 1985. *Prevention of post-harvest food losses: a training manual.* FAO Training Series No. 10, Rome, FAO.

Farrell, G., Hodges, R.J. & Golob, P. 1996. Integration of control methods for stored product pests in East Africa. *In* G. Farrell, A.H. Greathead, M.G. Hill & G.N. Kibata, eds. *Management of farm storage pests in East and Central Africa*. Proceedings of the East and Central Africa Storage Pest Management Workshop, Naivasha, Kenya, 14-19 April 1996.

Floyd, S. 1998. When is quantitative data collection appropriate in farmer participatory research and development? Who should analyse the data and how? (Unpubl. working paper) Natural Resources Institute, University of Greenwich, UK.

Galpin, M., Dorward, P. & Shepherd, D. 2000. *Participatory farm management methods for agricultural research and extension needs assessment: a manual.* Reading, UK, Departments of Agriculture and Agricultural Extension and Rural Development, University of Reading.

Marsland, N., Wilson, I., Abeyaekera, S. & Kleih, U. 2000. *A methodological framework for combining quantitative and qualitative survey methods.* Chatham, UK, Natural Resources Institute, University of Greenwich.

Marsland, N. & Golob, P. 1996. *Rapid rural appraisal of post-maturity issues in the central region of Malawi.* Chatham, UK, Natural Resources Institute, University of Greenwich.

Natural Resources Institute. 2002. *Crop post-harvest science and technology*, Vol. 1, *Principles and Practice.* P. Golob, G. Farrell & J.E. Orchard, eds. Oxford, UK, Blackwell Publishing.

Natural Resources Institute. 2004. *Crop post-harvest science and technology,* Vol. 2, *Durables.* R. Hodges & G. Farrell, eds. Oxford, UK, Blackwell Publishing.

Smith, R.H. 1994. Rodent control methods: non-chemical and non-lethal chemical. *In* A.P. Buckle & R.H. Smith, eds. *Rodent pests and their control.* Wallingford, UK, CAB International.

Stathers, T., Mvumi, B., Chigariro, C., Mudiwa, M. & Golob, P. 2000. Grain storage pest management using inert dusts. DFID Crop post-harvest programme final technical report. Chatham, UK, Natural Resources Institute, University of Greenwich.

Walker, D. J. & Farrell, G. 2003. *Food Storage Manual*. Natural Resources Institute, Chatham, UK and World Food Programme, Rome.

FAO AGRICULTURAL AND FOOD ENGINEERING TRAINING AND RESOURCE MATERIALS

1 Good practice for the small-scale production of bottled coconut water (E F S)
2 On-farm post-harvest management of food grains (E)

Availability: December 2009

Ar	+	Arabic	Multil – Multilingual	
C	+	Chinese	*	Out of print
E	+	English	**	In preparation
F	+	French		
S	+	Spanish		

Copies of FAO publications can be ordered from the online catalogue at:
http://www.fao.org/publishing/

or from the

Sales and Marketing Group
FAO Communication Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy.

E-mail: publications-sales@fao.org
Fax: (+39) 06 57053360
Web site: http://www.fao.org/icatalog/inter-e.htm

On-farm post-harvest management of food grains

A manual for extension workers with special reference to Africa

There is clear evidence that higher quality produce fetches higher prices and simple post-harvest management practices can improve the quality of produce and increase farm income. In this regard, farmers can benefit greatly from advice and training in post-harvest management to maintain quality and add value to produce.

This manual provides guidance on post-harvest management of food grains at the farm. It aims to guide extension workers on how to advise farmers in maintaining and adding value to the quality of their stored produce.

The manual first describes the role of the extension worker, and how to extend information and advice to farmers. It then deals with the major causes of losses and deterioration of food grains and, finally, how to prevent and control these through improved types of storage and good storage practices.

ISBN 978-92-5-106327-9 ISSN 1996-2738

9 789251 063279

I0959E/1/07.09/1000