MANUAL ON THE PREVENTION OF POST-HARVEST GRAIN LOSSES

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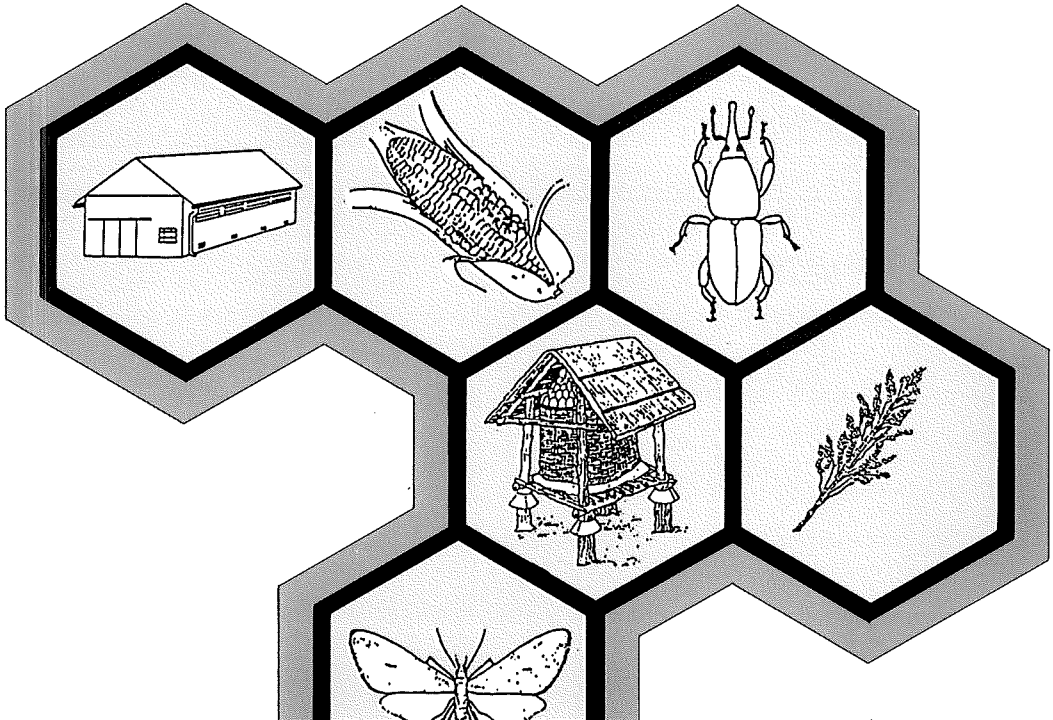

3.4 Further Literature

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4 Farm and Village Level Storage

4.1 Farm Storage Methods

Farmers traditionally store their grain in an unthreshed state. This is first because they often do not have the time to thresh the grain after harvesting, and secondly because they rely on the lower susceptibility of grain stored in husks to infestation from pests.

The storage period on farm level generally lasts 6 to 12 months.

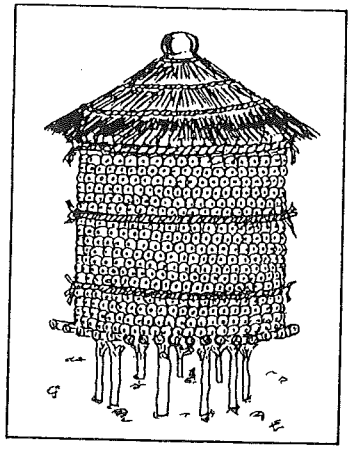
After harvesting, the grain is kept in a variety of different traditional storage containers which are in general perfectly adapted to the existing social, economic and climatic conditions and require only locally available materials.

Two basic forms of small farm storage can be distinguished: open and closed storage systems.

4.1.1 Open Storage Systems

In unfavourable hot and humid climatic conditions almost only open storage systems are used because the stored produce is still moist when it is put into storage.

Platforms resting on wooden stakes are very widespread, on which cobs or panicles are stacked in layers. A straw roof affords protection against the rain.



Crops are also occasionally to be found hung up in frames or under the roof of houses. In the latter case, the fire underneath is used to dry them and to repel insects.

Open systems are generally very simple constructions where storage hygiene is difficult to practise.

Advantages:
- The strong natural ventilation enables the produce to continue drying in storage.
- The development of fungi is restricted by the continuous aeration.

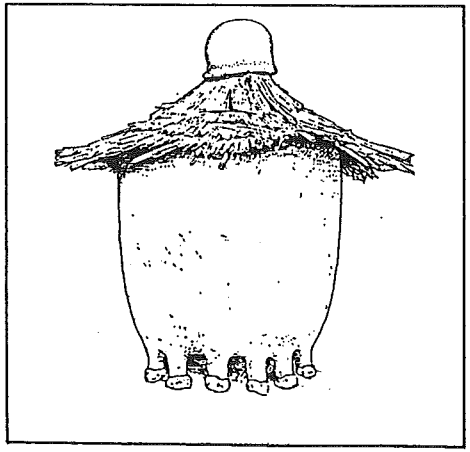
Drawbacks:
- Insects, rodents and birds have unrestricted access to the stored produce.

4.1.2 Closed Storage Systems

In arid regions, for the storage of sorghum, millet, pulses paddy and peanuts, use is made primarily of closed

storage containers made of mud, often mixed with chopped straw, which is known as "banco". The crops are generally stored in a threshed state. Problems with moisture or condensation are virtually unknown due to the low moisture content of the stored produce and the excellent insulation capacity of the mud used.

These "banco" containers are to be found in all shapes and sizes. They are usually closed with a lid and protected against rain with a straw roof. Large stones serve as a foundation and prevent any ground moisture from entering.



Calabashes, clay pots, wooden containers and clean oil drums are also in use and have often proved to be of good effect in small farm storage, especially for seeds and grain legumes.

In closed storage systems, condensation may occur especially in metal containers (e.g. oil drums). Particular attention must be paid to maintaining constant storage temperatures.

Advantages of closed storage structures:

- Usually afford good protection against penetration by pests.
- Cool and dry microclimate, particularly in mud constructions.
- Closed containers allow airtight conditions where oxygen is used by the respiration of pests and grains leading to the self-destruction of pests. The remaining oxygen is sufficient to maintain the germination ability of seeds.

Drawbacks:

- Mud constructions are not very resistant to rain making regular repair work or rebuilding necessary. Cracks provide ideal hiding places for insects.
- There is a danger of condensation, particularly in metal containers.

Small farm storage in underground stores (pits) is a special form of a closed storage system and has been repeatedly referred to in the literature as a promising method of storing grain. There are no doubts as to the advantages of such a largely airtight and cool form of storage not affected by any fluctuations in temperature.

If the pit is kept satisfactorily air- and watertight the development of insects and mites as well as the growth of moulds can be reduced to a minimum.

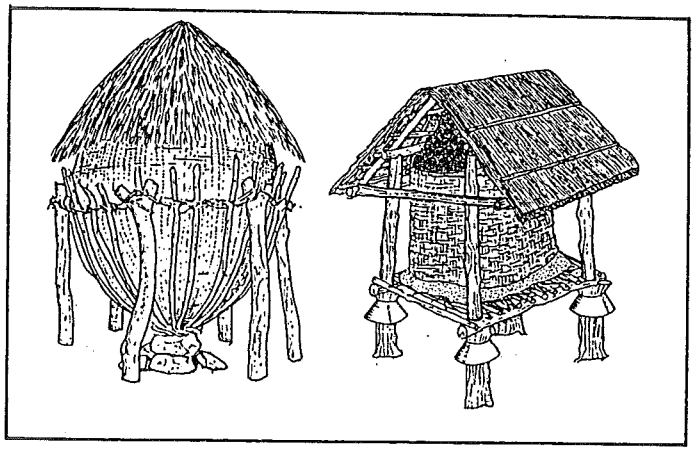
A suitable site must be chosen with the right type of soil. The entry of both ground and rain water must be prevented and the pit walls should be waterproof.

In certain areas underground stores are a recommendable alternative to the known small farm storage systems.

4.1.3 Semi-Open Storage Systems

Semi-open storage structures are particularly widespread in semi-arid regions. They include containers made of woven twigs or straw as well as wooden frames with a straw mat on which the commodities are placed. Crops are generally stored in an unthreshed state, i.e. in cobs or panicles.

Contact to the ground (moisture!) is prevented in a similar fashion to closed systems by means of stone foundations. A straw roof affords protection against the rain.



Semi-open storage systems give better protection against weather conditions but do reduce aeration and provide no obstacle for pest entry.

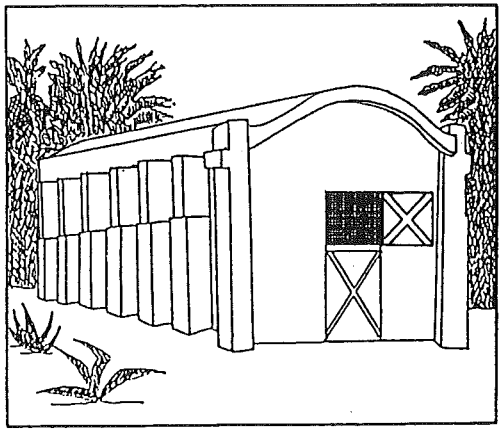
4.2. Village Level Storage

Food storage on village level in form of cereal banks is growing in importance, particularly in Africa. Cereal banks are managed by cooperatives or groups of farmers. They assure food security to the village community and provide farmers with the opportunity to sell their surplus when they can obtain better prices.

These stores with a capacity of between 10 and 50 t often have constructional features which do not allow low-loss storage. Essentially the same principles as for the construction of large stores apply for building the smaller cereal banks (see Section 5.1.1).

The GTZ Post-Harvest Project has therefore developed an improved type of a village store with a capacity of around 25 t, which can be extended as required.

The walls are made of cement bricks, the domed roof of reinforced concrete.



The advantages of this type of store are as follows:

- Easily to be built by the village community in self-help with expert supervision (see also Section 4.5)
- Best storage hygiene possibilities
- Favourable temperature conditions as a result of the material and shape of the roof (in contrast to the usual corrugated iron roofs)
- Good sealing and thus fumigation possibilities
- Ventilation openings operable from the outside
- Safe against penetration by insects or rodents
- Durable construction

Another construction feature which can be recommended for storage on a village community level is the use of air-dried mud bricks. The walls are plastered with cement mortar. A suitable supporting structure enables the roof to be built of bitumen and mud up to a certain store capacity.

4.3 Drying

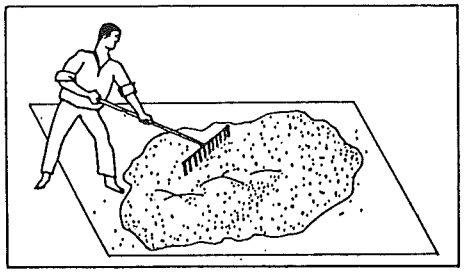
4.3.1. Sun Drying

Products must be dried to a sufficiently low moisture content before storage. This is particularly difficult in humid areas.

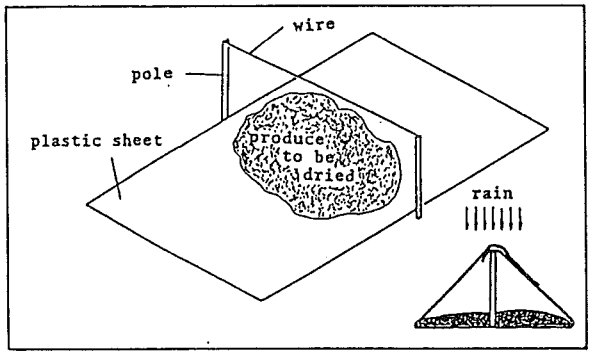
The traditional methods make use of sun and wind or fire. The produce is placed on the ground, on platforms or on special drying racks. When drying produce in the sun directly on the ground, the produce must be protected from absorbing any soil moisture by using sheets or mats.

The thickness of the layer of cobs, panicles, pods or grains must not exceed 5 cm in order to ensure good and even aeration.

The produce must be turned over regularly in order to dry it evenly.



In the evening, the produce must be put in a pile and covered.



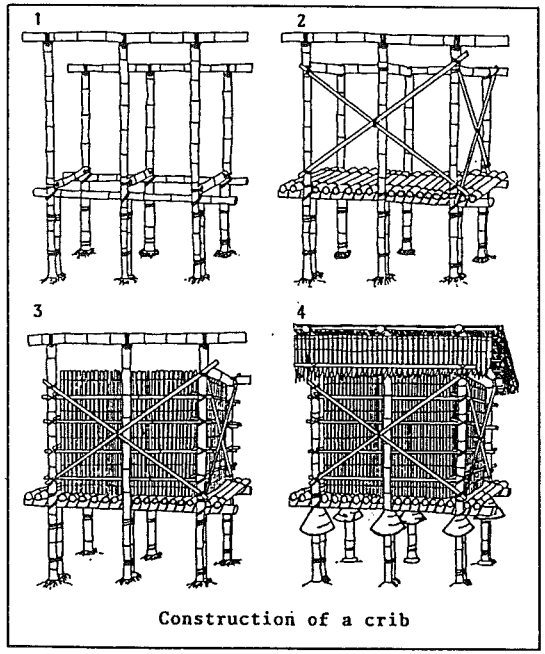
On special drying places there is always the risk of pest contamination. It is thus absolutely essential to keep these places clean.

Heat damage may result from too much exposure to the sun radiation or when drying the produce above a fire (grains cracking, losses in germination ability). Care should be taken not to exceed the following temperatures:

Beans : 35°C
Seeds : 43°C
Cereals: 60°C

4.3.2 Cribs

A drying frame or crib, developed in Nigeria, has proved to be of exceptional value, particularly in drying maize cobs.



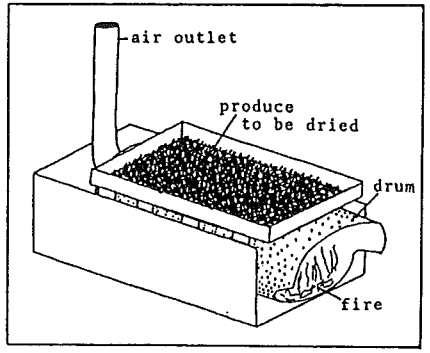
Construction of a crib

The crib consists of a wooden or bamboo frame with walls made of wire mesh or wooden slats and a thatch roof. It has a maximum width of 60 - 80 cm. This guarantees good aeration and drying, even in humid regions. The cobs are left in the cribs for up to 3 months, depending on weather conditions, and thereafter put into the store. In some areas the cribs also serve as stores.

4.3.3 Bush Dryers

Bush dryers are constructions built in the form of a tunnel made of mud or metal drums, and through which hot air is conducted with the aid of an open fire. The produce, spread out on a platform positioned above the tunnel, is dried by heat radiation. Adequate drying can, however, only take place if the produce is spread out in layers no thicker than 2 - 3 cm. As there is generally no possibility of regulating the heat, overheating and damage to the produce may easily result.

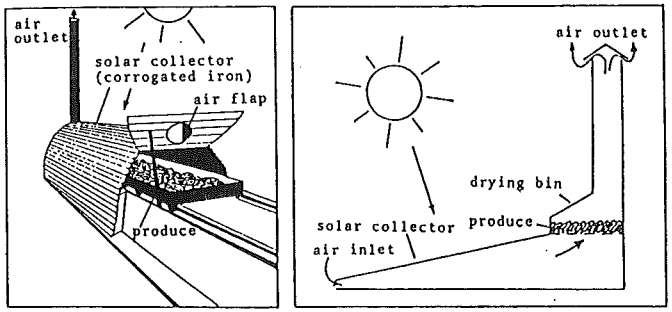
Bush dryers are easy to build and very effective. They are run on wood or charcoal as well as crop remainders.



The use of bush dryers is, however, not undisputed because of the resources needed to fuel them.

4.3.4 Solar Dryers

Solar dryers are based on the principle of conducting air heated by the sun (collector) through the produce.



The advantages of solar dryers as compared to the traditional method of sun drying in the open air are:
- Temperature control is possible
- Protection of produce from adverse weather conditions and from infestation by pests
- Low running costs

The drawbacks are:
- Relatively high purchase costs
- Very limited capacity

Unfortunately, solar dryers have not yet been established to the desired extent due to socio-cultural, technical and financial reasons. In addition, cloudy skies at the time the crops are harvested in many regions limit the use of solar energy.

The technical problem of creating a sufficiently strong current of air in the dryers has not yet been solved. This air stream is necessary in order to evacuate the saturated air after having passed through the produce. Otherwise condensation or mould can occur.

Simple solar systems which take into account the demands of the users are nonetheless likely to gain in importance in the future.

4.4 Pest Control on Farm Level

Preventive measures with regard to storage hygiene are of decisive importance for pest control and in maintaining the quality of the stored produce.

By the term storage hygiene, we mean the use of all technical measures without the application of chemicals.

Perfect storage hygiene is the basic prerequisite for successful storage and for the effectiveness of all on-going measures, such as the use of insecticides or fumigants.

All hygiene measures are very simple, particularly effective and cheap, and can thus be performed by any farmer with little effort.

4.4.1 Traditional Methods

Traditional methods of pest control will certainly continue to play a role in small farm storage in the

future. They cause little cost, but their effect is limited, which excludes the possibility of any general application of such measures.

Alongside religious practices which are used to protect the crops, traditional pest control is largely based on the following methods:

- Preventive measures taken before harvesting (S. 4.4.1.1)
- The addition of various substances to the stored produce (see Section 4.4.1.2)
- Physical methods (see Section 4.4.1.3)

A departure from traditional methods of pest control in favour of modern storage techniques has in the past often led to considerable errors due to insufficient examination of the new methods.

Generally speaking, farmers will accept small, easily-comprehensible and low-cost alterations to their storage methods with the aim of reducing losses. They are, however, not willing for various reasons to make any radical alterations to the traditional storage systems to which they are accustomed - and often correctly so.

4.4.1.1 Preventive Measures Taken before Harvesting

The following methods contribute to preventing pest infestation from the field into the stores:

- Selection of store location (removed from any potential sources of infestation)
- Crop rotation and mixed cropping

- Choice of the time of harvesting
- Selection of less susceptible cereal varieties

4.4.1.2 Addition of Substances to the Stored Produce

4.4.1.2.1 Admixture of Mineral Substances

There are a variety of different materials which can be added to the stored produce:

- fine sand
- clay dust
- quicklime
- wood ash

The admixture of mineral substances to the harvested crops causes invisible injury to the protective wax layer of stored food pests, leading to dehydration. As these substances fill in the spaces between the grains, locomotion is restricted with regard to finding partners for reproduction. Respiration difficulties also result.

The use of wood ash is an efficient method of pest control in practice all over the world. Its disadvantages lie in the effect it may have on the taste as well as in the fact that the success of this method depends on a considerable amount of ash being added. This is generally 300 - 400 g of ash per kg of stored produce. This excludes the possibility of using this method in case of larger quantities. The use of ash should, however, certainly be encouraged wherever it is practicable, such as in small farm seed storage.

When adding mineral substances, the amounts required are around 50 - 100 g per kg of stored produce. In the case of fine sand, however, around 1000 g/kg are required.

4.4.1.2.2 The Admixture of Substances of Plant Origin

Traditionally many different types or parts of plants are used against stored product pests.

Although very promising results have often been achieved in laboratory tests with plant material, their effectivity under practical storage conditions are limited.

The following substances are known:

- leaves, crushed seeds, their extracts and oil from the Neem tree (Azadirachta indica)
- Pyrethrum, an extract from the flowers of an African species of Chrysanthemum
- crushed bark from the cailcedrat tree (Khaya senegalensis)
- vegetable oils (groundnut oil, castor oil, palm oil)
- hot pepper

The dosages of plant substances required are generally around 50 g per kg of stored produce.

The addition of vegetable oils has shown to be of particular use in protecting legumes against pulse beetles (Bruchids).

Farmers are generally able to obtain the oil required by grinding the seeds themselves.

Losses in pulses can thus be effectively prevented with an amount of 5 ml oil/kg. The oil is active against eggs and larvae. It has no effect on the adult pulse beetles which cause no damage anyway.

In addition, there are a number of other plant substances used by farmers in pest control on a local level.

The way in which these substances take effect is complex and not only restricted to physical properties. Toxic, growth regulating and repellent effects are known.

The admixture of substances of animal origin does not play any great role in pest control. Cow dung is, however, used for coating the walls of small farm mud silos against hidden pests.

4.4.1.3 Physical Methods

Physical methods of pest control are applied both preventively and curatively.

4.4.1.3.1 Mechanical Methods

- Removal of pests, infested grain or cobs by hand
- Sieving
- Winnowing
- Moving the grain (shaking, restacking)

When using methods which merely separate the pests from the stored produce and do not result in their death (e.g.

sieving), care should be taken to ensure that the pests removed from the produce are killed to prevent reinfestation.

4.4.1.3.2 The Use of Heat

- Spreading out the produce in the sun (larvae living in the grains will be killed, the adult insects which are sensitive to heat and light will flee).
  Avoid overheating!
- Storage of grain above the kitchen fire (heat and smoke will chase the pests)
- Heating in water (parboiling)
- Smoking or burning out storage containers (e.g. mud silos)

4.4.1.3.3 Airtight Storage

Sealed storage is ideally suited to control insect and mite infestation in dry grain without the use of pesticides. The principle of the method is namely the elimination of the oxygen that insects and moulds require for their growth as well as an increase of the CO_2 level (see Section 4.1.2). This is due to the respiration of the pests and grain.

In this context the importance of a good, sound construction or container cannot be overstressed. Thermal insulation is important.

Airtight storage is particularly applicable for long-term storage in warm dry areas. It might be advisable, however, not to store seed grain for more than a few months.

In tropical countries, where the relative humidity is at the optimum for mould growth, airtight storage is generally not recommended.

Potential dangers with this storage method can be reduced by careful management and particularly by ensuring a more or less even temperature in the store which exclude the risk of condensation.

4.4.2 Biological and Integrated Means of Pest Control

Biological and integrated means of pest control are dealt with in greater detail in Chapter 10, Section 2. The use of natural enemies (predators, parasites), of specific microorganisms, as well as food traps and varieties more tolerant to storage pests may grow in importance in small farm storage in the future.

With regard to biological control of stored product pests first investigations have shown promising results.

4.4.3 Chemical Methods

For centuries, farmers have relied on the protective effects of husks or pods and have selected traditional varieties with a low susceptibility to storage pests.

This confidence is by all means justified. Therefore any interference in the farm storage system in order to avoid the drawbacks of traditional methods by an increased use of insecticides must be carefully examined with regard to social and economical effects.

As the traditional means of pest control will be overcharged with increasing production and stored quantities all over the world, efforts are being made to introduce changes to traditional storage systems. These efforts are generally centred around the use of insecticidal dusts which are mixed with the produce.

This section deals with the application of dust formulations on farmer's level. Information on the possibilities and limitations in the use of chemical insecticides, the choice of suitable insecticides, safety aspects and others is provided in Chapter 8.

The following points must be taken into account when using chemical means of pest control:

- Toxicity of the insecticide (user protection) (see Section 8.1.7).
- Economic viability of an insecticide treatment. Experience has shown that the treatment of cobs of maize in husks is not always economically viable, particularly in cases when the maize has already been heavily infested in the field.
  This also applies to the treatment of stored produce which does not remain in the farmer's storage container for longer than 2 - 3 monts.
- Availability of the correct insecticide at the right time and in the right place
- Suitable, i.e. small package sizes with labels bearing instructions for correct use
- Farmers knowledge on dealing with insecticides based on appropriate extension measures

Therefore chemical insecticides can only be propagated when these facts are assured and a functional supply system and competent extension service is available.

Insecticides are generally not used in the best possible way on a farm level. Of the many different formulations available, generally only dust formulations are used although spray applications are more effective under certain conditions.

The following **areas of application** are possible in small farm storage:

- Space treatment of stores (dusting, spraying, smoking) provides good preventive pest control.

- Treatment of the stored produce by adding insecticide dust either by mixing it with the stored produce or applying it in layers as well as treatment by spraying or by smoking.

4.4.3.1 Dusting

4.4.3.1.1 Dust Formulations

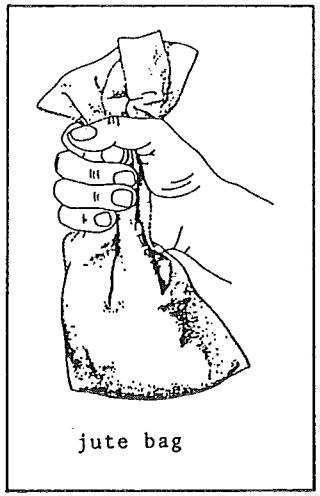
Dust formulations of insecticides are sold ready for use and contain 0.1 - 5 % active ingredient. The formulations contain additives which increase the adhesive power to the stored produce. Dust formulations are suitable for mixing with grain, for applying in layers in the stored produce (sandwich method) and for surface treatment of individual bags, bag stacks and stores. The most common insecticides at present in use are:

Name of Active Ingredient (a.i.)	Name of Commercial Product (c.p.)	Application Rate ppm	Application Rate g c.p./ 100 kg produce
Organophosphorous compounds:			
Fenitrothion	Folithion 1 % D	10	100
	Sumithion 1 % D	10	100
Pirimiphos-methyl	Actellic 2 % D	10	50
Chlorpyrifos-methyl	Reldan 2 % D	10	50
Methacrifos	Damfin 2 % D	10	50
Bromophos	Nexion 2 % D	10	50
Malathion	Malathion 2 % D	8-12	40-60
Pyrethroids:			
Deltamethrin	K-Othrin 0.2 % D	1	50
Permethrin	Permethrin 0.5 % D	2.8	55
Fenvalerate	Sumicidin 1 % D	5	50
Cyfluthrin	Baythroid 1 % D	2	20

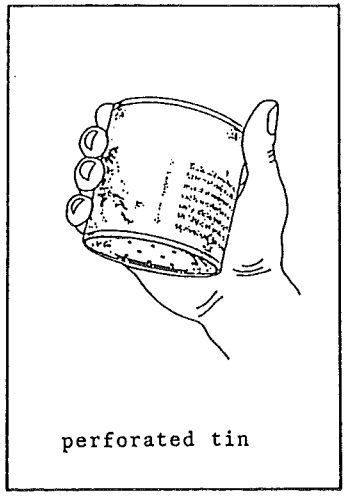
Information on the correct choice of active ingredients is provided in Section 8.1.6.

4.4.3.1.2 Duster

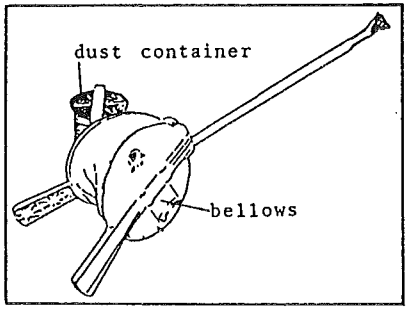
Dust formulations are applied by means of a duster. There are very cheap and effective models which can easily be made locally or are available on the market:

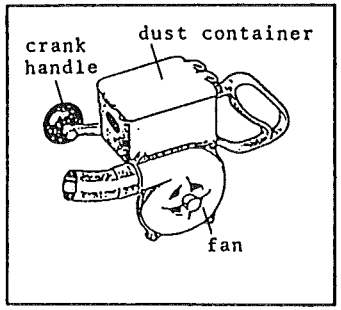


jute bag



perforated tin





4.4.3.1.3 <u>Application of Insecticide Dust: Admixture with Grain</u>

This method applies in small farm bag storage of loose grains. The dust is mixed with the grains as follows:

1 Pour the grain in a heap on the floor

2 Evenly distribute the required amount of insecticide on the heap

3 Carefully mix together insecticide and grain using a shovel

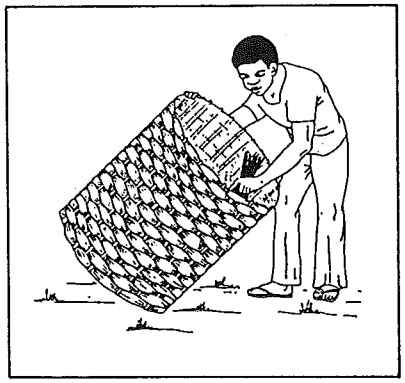
4 Check that the powder is evenly distributed

Bag and store the treated grain.

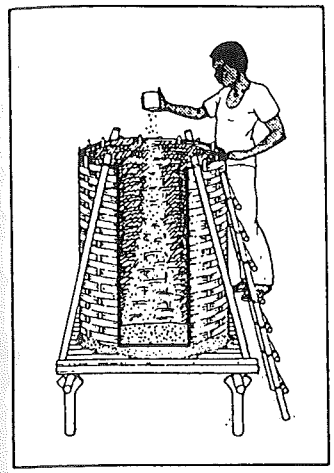
With larger amounts of grain (more than two bags) it is better to mix the dust with the entire heap by reshovelling it a number of times:

4.4.3.1.4 **Application of Insecticide Dust: Sandwich Method**

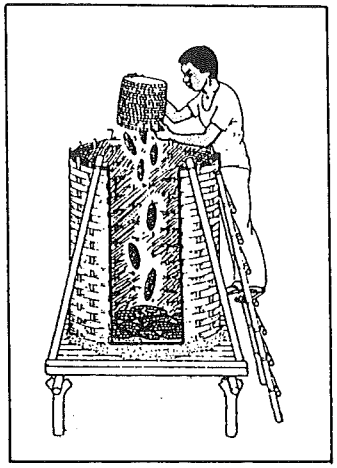
The sandwich method is suitable both in the storage of maize cobs as well as for millet. The stores must be thoroughly cleaned.



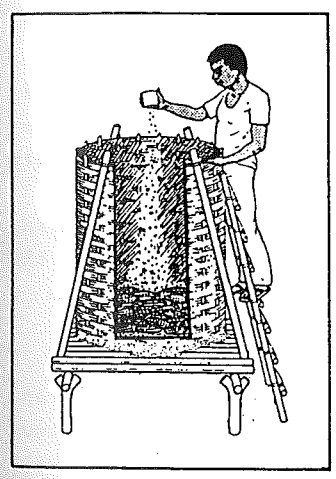
Storage and the application of insecticide may then commence:



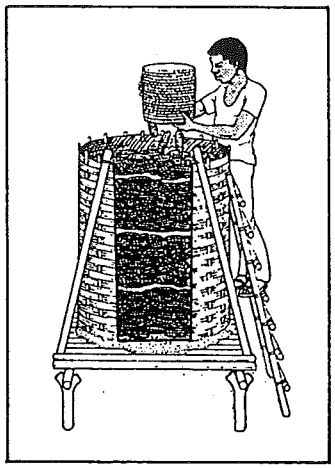
1
Sprinkle the inside walls and floor with a fine layer of insecticide



2
Put in a layer of corn cobs (no thicker than 20-25 cm)

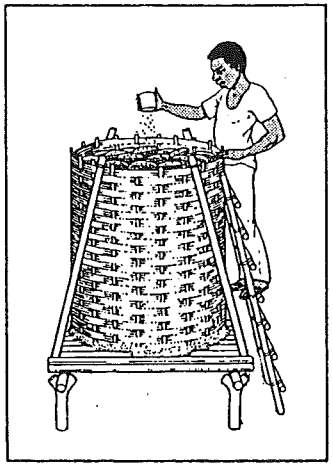


3
Sprinkle dust evenly over the layer of cobs



4
Put in more layers of cobs and dust each layer

Finally dust the top layer thoroughly:



The degree of field infestation of maize depends largely on the close cover of cobs provided by the husks.

Studies have shown that storage of cobs protected by the husks can be as effective in preventing losses as a treatment with insecticide.

Removing the husks before applying any insecticide can, however, be of considerable advantage in cases of previous field infestation as insects already inside the cobs will then come in contact with the insecticide.

4.4.3.1.5 **Dosage Calculations for the Application of Dust Formulations**

Application rates for dust formulations are given either in **g commercial product per 100 kg of grain** or in **ppm** (parts per million). **ppm** refers to the **amount of active ingredient** in the grain.

A value of 10 ppm means there are 10 weight parts active ingredient contained in 1 million weight parts of the stored produce. As 1 kilogramme contains 1 million milligrammes, 10 ppm means 10 mg of a.i. per kg of grain.

- **Application rate given in g/100 kg**

Information required for the calculation:
- Weight of the stored produce to be treated (in kg)
- Recommended application rate (in g/100 kg)

The amount of stored produce to be treated (in kg) is multiplied by the application rate (in g/100 kg).

Example: 500 kg of maize are to be treated using a 2 % dust formulation.

The recommended application rate is: 50g/100 kg

Calculation: $\frac{50\ g}{100\ kg} \times 500\ kg = \underline{250\ g}$

250 g of the 2 % dust formulation will be required to treat 500 kg of maize.

- Application rate given in ppm

Information required for the calculation:

- Weight of the stored produce to be treated (in kg)
- Active ingredient content of insecticide (in %)
- Recommended application rate (in ppm)

The dosage calculation is performed in four steps with the aid of the ppm table (see annex 1):

- The top row in the table lists various recommended application rates in ppm.
  Find the column referring to the given application rate of the insecticide being used!

- The column on the left in the table lists various active ingredient concentrations in %.
  Find the row applicable for the insecticide being used!

- Find the point where the applicable row and column cross!
  The figure stated there is the amount of the dust formulation (commercial product) in g which is necessary for the treatment of 100 kg of stored produce.

- Calculate the required amount of dust formulation for the actual amount of stored produce being treated.

Example: 300 kg of grain are to be treated with a 5 % dust formulation.
The recommended application rate is 10 ppm.

The point where the 5 % row crosses the 10 ppm column shows the required amount of the insecticide for 100 kg of grain: **20 g**.
This figure is converted for 300 kg of produce:

$$\frac{20\ g}{100\ kg} \times 300\ kg = \underline{\mathbf{60\ g}}$$

60 g of the 5 % dust formulation are thus required to treat 300 kg of grain.

- **Dosage calculation for the sandwich method**

In the sandwich method, the same dosage is applied as for an admixture of insecticide with the stored produce. The total amount is thus calculated on the basis of the quantity of stored produce in kg as described above.

For each layer with a maximum thickness of 20 cm the corresponding amount of insecticide is calculated according to its weight. Care must be taken to have layers of the same thickness.

It is recommended to retain a part of the calculated quantity of insecticide to treat the floor, walls and the top of the storage container during filling.

When storing the produce on platforms, retain a part of the insecticide from each layer to dust the outside of the stack once all the produce has been put into storage.

Example: Maize cobs are to be treated using a 2 % dust formulation.
The recommended application rate is 50 g/100 kg.

2 baskets of maize cobs make up one layer. The average weight of the baskets is 60 kg.
The overall weight of the first layer is thus:

$$2 \times 60 \text{ kg} = 120 \text{ kg}.$$

Therefore, $\frac{50 \text{ g}}{100 \text{ kg}} \times 120 \text{ kg} = \underline{\mathbf{60 \text{ g}}}$

of the dust formulation must be used for the treatment of the first layer including floor and part of the wall.

2 bags of maize cobs and 60 g of insecticide should also be used for each subsequent layer including the final coverage.

There are sometimes difficulties for farmers in calculating the weight of produce being treated. It is best to weigh the produce before storage or count the number of bags or baskets emptied in the store. The average weight of one bag or basket must then, however, be known.

4.4.3.2 Application of Liquid Formulations

Should liquid formulations be used in small farm storage, please refer for application instructions and dosage calculations to Chapter 8.

4.4.3.3 Fumigation

In many areas in Africa, Asia and South America, grain is stored in sealed containers made of mud. Fumigation of these stores is a highly promising method of pest control even on a small farm level, particularly as this technique is simple, cheap and effective and does not leave any residue in the stored produce.

Problems and risks may, however, occur as a result of incorrect handling of fumigants by untrained farmers. Therefore fumigation on a small farm level can only be practised in cases where storage facilities can be well sealed, where advice and training for users are available and where fumigants are suitably packed.

4.5 Further Literature

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5 Central Storage

As a result of extensive social and economic changes (e.g. expansion of trade with basic foodstuffs, supplies of food aid, increase in urbanisation), central stores, usually under state control, have grown both in number and importance in all countries.

5.1 Storage Facilities

It is quite apparent that a number of the storage facilities set up in tropical and sub-tropical countries are unsuitable for storing goods without a reduction in quality and considerable losses.

Although appropriate warehouse designs have been provided as far as suitable construction material, ventilation facilities and favourable constructional properties are concerned, little use is made of these.

This can be observed even in recently-built stores and has led to the following considerations:

- Easy-to-erect **corrugated iron halls** made of prefabricated parts may be justifiable for short-term storage in case of emergencies. Buildings of this kind are unsuitable for long-term storage due to the poor control of climatic conditions and condensation problems.

- Under arid climate conditions, instant erection **flexible plastic silos** can be used for bag storage of locally produced grain as a part of maintaining security reserves. To avoid condensation problems it is a