Agrodok 18

Protection of stored grains and pulses

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First edition: 1985
Fourth revised edition: 2000
Fifth edition: 2004

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Printed by: Digigrafi, Wageningen, the Netherlands

ISBN: 90-77073-49-3

NUGI: 835

Foreword

This manual deals with problems concerning losses of stored products by storage pests: moulds (fungi), insects and rodents. It is targeted at those who are involved with providing information on storage to farmers and co-operatives.
The Agrodok describes the main storage pests and gives explanations of preventive and protective practices. Special attention is given to the use of natural materials in protecting storage products.
You will also find some information on chemical treatment of stored products against pests.
Another title in the Agrodok series (No. 31): "The storage of tropical agricultural products", is another useful book about storage. The two Agrodoks are complementary.

We would greatly appreciate it if you would write us your experiences on successful local methods to protect storage products. Where possible, they will be included in a future revised edition.
Thanks are due to all those who have contributed and have provided useful information or comments for revision of this booklet.

The author, Wageningen, 1991.

Foreword to the revised edition

A slight revision of this Agrodok has been carried out, including an update on the chemicals mentioned. Agromisa prefers to advise not to use chemicals for storage protection, because chemicals are poisonous for human beings too. But we admit that sometimes using chemicals is necessary in order to reach a better food security. We follow the international regulations on allowance of chemicals. We realise however, that many chemicals which are prohibited are still being sold, especially in developing countries. We advise the reader not to use these.

The Agrodok co-ordinator, Wageningen, 2000

Contents

1 Introduction

Everywhere in the world stored products are attacked by a number of storage enemies. Three major groups of storage enemies are:

- fungi
- insects
- rats and mice

These organisms can damage a considerable part of the stored product. In many cases small improvements in storage methods may already lead to much better protection of your storage product and thus to less losses.
A good storage building is one thing, good safety measures another. Therefore this Agrodok concentrates on the prevention of losses in stored products, particularly with regard to drying, temperature regulation and hygiene.

However, good storage practices combined with good hygiene, adequate drying and all other safety measures will not always be effective in preventing storage losses. Storage pests may still manage to reach the product and leave a trail of devastation work. If this occurs you will have to take other measures to protect your storage product.

There are many ways of protecting local storage products. Time honoured methods such as the use of natural materials like plants, minerals and oil are still very effective. Due to the introduction of chemicals many traditional storage treatments are often forgotten. In this Agrodok some examples of traditional storage methods are given to bring them back into memory. Not every method will be effective in your situation; try some of them out and experiment for yourself.

In case of emergency some information about chemicals is provided. This information is very limited. It is not possible to provide many details here. Ask your agricultural extension worker for more informa-

tion. In the case of small farm storage the use of chemicals will not always be very profitable i.e. the costs will be much higher than the benefits. Keep this in mind!

1.1 Why only grains and pulses

This booklet deals only with grains and pulses because these are considered the most important storage products for small-scale farmers in the tropics.

It is also recommended that you use Agrodok 31; "The storage of tropical agricultural products" in combination with this Agrodok. The two manuals are complementary.

2 Storage pests

The three major storage pests are fungi, insects and rodents. They are very different and described in this chapter.

2.1 Fungi

Fungus in stored grain is the most difficult enemy to be recognized, for you cannot see it as easily as the two other major pests: insects and rats. However, spores of fungi are present everywhere! Spores (comparable with very little seeds) are spread by wind and insects. It is impossible to keep fungal spores out of the storage environment.

Fungi are plant-like organisms, and spores are the single-celled bodies by means of which they reproduce themselves. To stay alive they feed on stored products either in raw or processed form. Due to the breakdown of the product tissue, foodstuffs acquire a bad taste and become less nutritious. The germination power of seeds will then deteriorate.
Some fungi produce a sort of poison which can make you very ill.
In an early stage of infection characteristics such as discolouration, change in texture, the presence of green, blue, grey, white or black fruiting bodies of the fungus or an unpleasant smell are not always very obvious. Clear signs of infection in large quantities of grain are the so called 'hot-spots'. Information about hot-spots will be given in Chapter 2 in the section on temperature regulation.

Humidity

Fungi develop best in a warm and humid atmosphere. Humidity in particular, is crucial for the development of fungi. Even at a low temperature some mould development may occur if the relative humidity of the air is high, which means that there is a lot of water vapour in the air. A dry atmosphere prevents the germination of fungal spores and thus the development of fungi. However a dry atmosphere will not kill the spores, as they are highly resistant to dry conditions. They can remain viable for quite a long time.

Drying is the best remedy
By now it will be clear why preliminary drying of the storage product combined with keeping it dry is the best remedy against fungi. Chemicals are not necessary as long as your storage product is dried properly **and** neither water nor humid air can enter the store and make the grain damp.
More information about drying is given in Chapter 2.

2.2 Insects

Insects need food, air and water to live. In many cases stored grain provides a perfect place for insects to live and grow because food, air and water are available in sufficient quantities. This is why some insect species infest stored products.

The two major insect pests in stored grains and pulses are **beetles** and **moths**. The larvae of both groups of insects are totally unlike the adult forms. They look a little like worms. Sometimes you do not discover them because they develop inside the kernel. The development of moths and beetles from egg to adult insect is shown in figure 1 (next page).

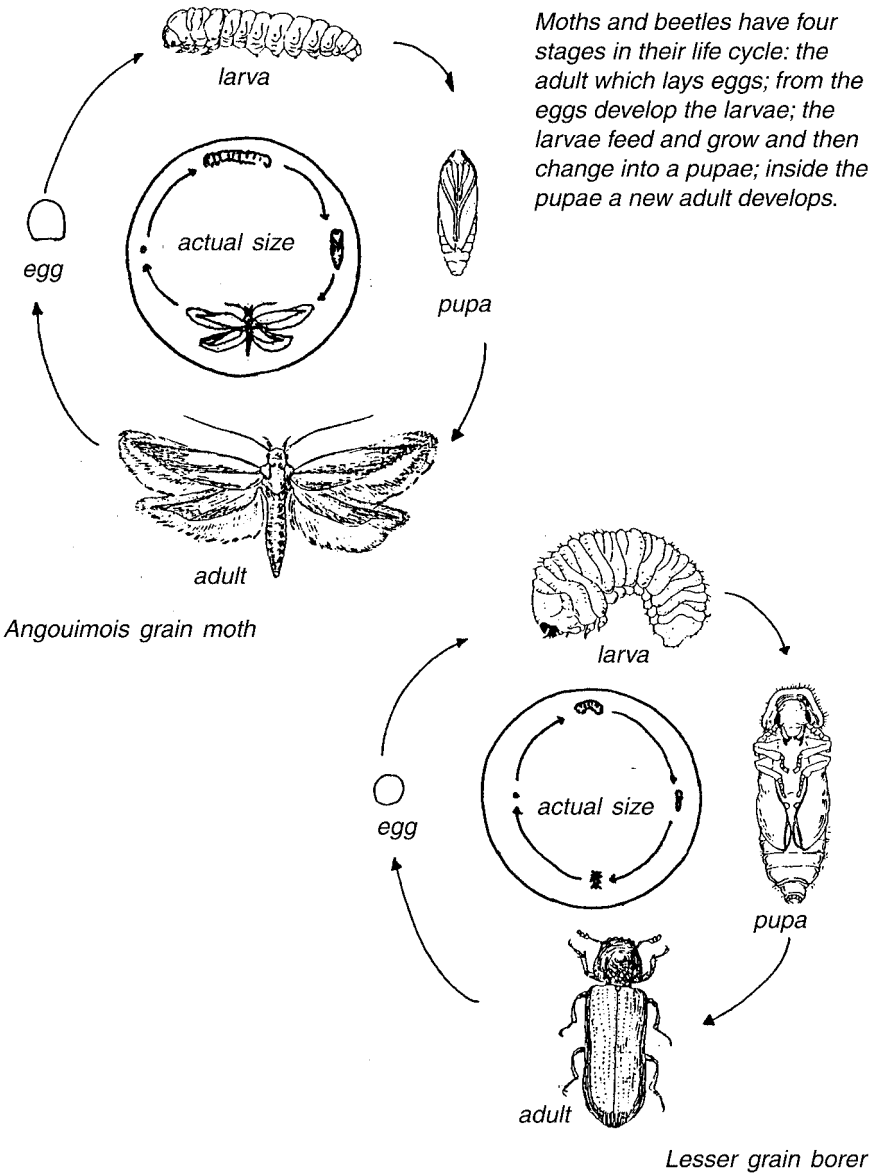
The practice of drying is not very effective against insect pests, as their drought tolerance is very high.

Primary, Secondary and Tertiary Pests

Some insects prefer certain kinds of grains and not all insects eat the same part of the grain kernel. Which type of grain they like and which part of the grain they eat depends upon the insect species.

Storage insects can be divided into three different groups:

1 Some insect species such as the Angoumois grain moth, the Lesser grain borer and the Rice weevil are **primary pests**. These insects can break down the hard seed coat of the undamaged grain. Some of these species lay their eggs inside the kernel and the growing larvae eat the inside of the kernel. Other species lay their eggs on the outside of the kernel. The hatched larvae eat their own way through the hard seed coat towards the very nutritious inside.



Moths and beetles have four stages in their life cycle: the adult which lays eggs; from the eggs develop the larvae; the larvae feed and grow and then change into a pupae; inside the pupae a new adult develops.

Figure 1: two examples of a life cycle

2 Insect species of the so-called **secondary pests** are not able to break through the hard undamaged seed coat. They follow the first attackers. These **secondary pests** feed on the grain which has broken and cracked seed coats. Secondary pests, like the Rusty grain beetle, will not attack healthy, undamaged grain. They will only attack spoiled grains.
3 A third group of storage pests feed on broken grains, grain dust, and powder left by the previous groups. Insects belonging to this group are the **tertiary pests**.

The primary pests are the most dangerous ones. They damage the intact kernel so that the larvae can develop inside the kernel. In this way they also provide secondary and tertiary pests with the opportunity to infest the store, as the damaged kernels become a food source for them.

Put only undamaged grains into the store
Now it will be clear to you why it is very important to introduce, if possible, only undamaged kernels and pulses into the store. In kernels with a little puncture there may be larvae of primary pests. Bringing these kernels into the store is the same as introducing an adult primary pest. If you have a lot of broken kernels in your storage product, secondary and tertiary pests will be attracted.

2.3 Rodents

Rodents cause considerable damage to field crops and stored products. There are four ways in which rodents do damage to stored products:

- They consume a quantity of the product.
- They spoil part of the product with their droppings.
- They gnaw holes in the packing material causing waste. Jute bags can be seriously damaged in this way. Products stored in bulk are less vulnerable because rats can only nibble away the surface.
- Rodents are also carriers of diseases which are harmful to man. People can get these diseases from eating and handling grains contaminated by rodent faeces, urine or parasites which they carry.

Unlike the insects and fungi which infest the storage, rodents will plunder stores whatever the temperature or moisture content of the grain or air.

3 Inspection and identification

3.1 Inspection

Inspection of the stored products should be carried out frequently so that you will discover an infestation in an early phase and be able to take measures in time. There are several methods to determine the infestation degree very precisely, but for small-scale storage, a general inspection will do.You should check your grain and store regularly by looking for insects, fungus infestation and rodents. Check for:

- **Insects**: If the grain is stored in sacks, hit a sack against the floor. Then let it rest in a shaded place (no direct sunlight). After a while check to see if there are any weevils on the outside of the sack. Also inspect some grain from inside the sack or container. Dump part of the grain out of the sack or take some out from the middle of the storage container. Check the grain sample for the presence of insects or signs of insects either by putting the grain through a sieve or sorting through it by hand.
- **Fungus**: Smell inside the sack or container. If the stored product is infested by fungus, there is a mouldy smell. Also inspect some rains from the inside of the sack or container by sorting it by hand, look for mouldy grains. If there is an infestation put the stored product out in the sun to dry. Do this regularly.
- **Rodents** you probably meet by surprise, because they will hide when they hear you coming. You can check for signs of rodents, such as droppings, holes gnawed in the bags, or their smell.

3.2 Identification of pest insects

Identifying the main pests in your store is important in order to be able to:

- assess whether the insects found are likely to cause serious damage (e.g. primary pests);
- decide which control measures should be taken since many treatments are selective in their action and many pests have their specific strong and weak characteristics.

Unfortunately the majority of storage pests are so small that it is very difficult for non-specialists to identify them. A self-made reference collection (figure 2) may be of great help. You can make such a collection by collecting the most common pest species in your particular area and have them identified by a specialist.

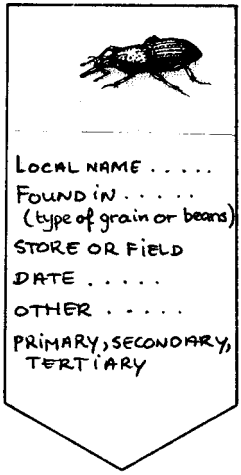


Figure 2: Example of a refernce card for one insect species

NOTE
Not all insects present in stored grain are necessarily grain pests. There may be insects feeding on fungi: this causes only incidental damage to the stored product. Others may be predators or parasite of the grain pest. *These are beneficial!*

3.3 Identification of rodents

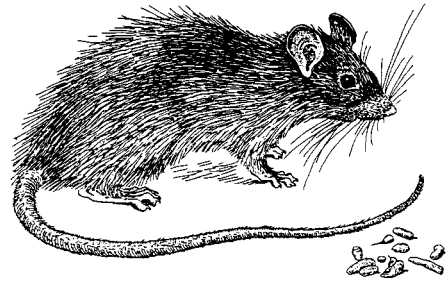
The type of rat and mouse may differ depending upon the country or the area. In many parts of the world there are three important rodents which can be found moving between houses, fields and storage facilities looking for food, water and good living conditions. These three are the black rat, the brown rat and the house mouse. To control rodents it is important to know which species is attacking the store. table 1 and figure 3 can be of some help to distinguish the above mentioned species.

All three species depend almost completely on the presence of human beings and their products. Human food and refuse allow these species to form large populations. Proximity to humans protects them from many natural enemies. Therefore rats and mice always can be found near man. It is not likely that a farmer will be able to free the farm of rodents completely. But he can and should control the number of rats and mice.

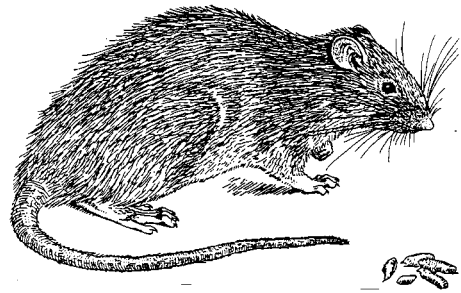
Table 1: Identification of the three most important rodents

	Black rat	**Brown rat**	**House mouse**
Synonyms	ship rat roof rat Alexandrine rat	common rat Norway rat sewer rat	
Scientific name	Rattus rattus	Rattus norvegicus	Mus musculus
Weight	250 g (120-350 g)	330 g (150-600 g)	16 g (15-25 g)
Length			
- head & body	16-24 cm	21-27 cm	10 cm or less
- tail	Longer than head plus body, 200-260 rings.	Shorter than head plus body, 160-190 rings.	Longer or the same length as head + body.
Appearance			
- eyes	Fairly large	Fairly small	Fairly small
- ears	Large; ears touch the eyes when flattened; sparsely haired.	Small; ears do not touch the eyes when flattened; furry.	Fairly large; the ears just cover the eyes when flattened; sparsely haired.
- snout	Pointed	Blunt	Pointed
- tail	Sparsely haired, thin, uniformly dark in colour.	Thick, often dark above and light below.	Some sparse hair, thin, darker coloured than body.
Colour	Dorsal hair is very dark grey to brown; the belly varies from very dark to light grey.	Upper parts dark brownish-grey; the colour lightens to the sides, belly and feet greyish-white.	Brown-grey with slightly lighter or white belly; sometimes black or brown-yellow.
Footprints hind foot	Length on average less than 4 cm.	Length on average more than 4 cm.	Length less than 2 cm.
Droppings (real size)	Usually sausage or banana shaped.	Usually spindle shaped.	Irregularly or spindle shaped.
Food	Omnivorous with a preference for seeds.	Omnivorous without any particular dietary preference.	Omnivorous, well adapted to feeding on dried seeds.
Water	Can survive for a long period without water.	Cannot survive for long periods without drinking water.	With sufficient food, it can survive for long periods without water.
Occurrence	Very widespread in (sub) tropical regions, mainly in dwellings, farm buildings and food stores, usually nests above ground.	Widely occurring in agricultural and urban areas in temperate regions and some tropical islands, elsewhere in tropics usually confined to ports.	Very widespread, especially in temperate and subtropical regions.

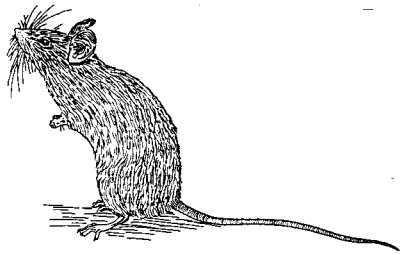
	Black rat	Brown rat	House mouse
Damage	Can eat a lot of grain; it is the most dangerous stored grain rodent.	Actively looks for grain in field and storage. Can eat a lot of grain.	Eats a lot of grain. Since mice do not eat the whole grain, they ruin more grain than they eat.
Further...	Especially dangerous because of its ability to jump and climb. They like to climb more than they like to dig.	This rat digs in the ground and can burrow under a wall.	



A: Black rat



B: Brown rat



C: House mouse

Figure 3: The three main rodents

4 Preventive measures against insects and moulds

Preventive measures against insects and mould start already at the time of growing the crops that will be stored later. In general it can be said that a farmer can influence the occurrence of pests in the stored crops by carefully choosing certain resistant varieties, planting or sowing and harvesting in the optimum season, properly treating the crop before storing, siting the store in a favourable place and keeping it very clean.

4.1 Measures in the field

Choice of varieties

When choosing the seed varieties, a farmer can already take into account the susceptibility of the crop to storage pests. Through experience the farmer can learn to select varieties which are pest resistant.
For example, a hard seed coating or tightly closed husks act as a barrier to larvae which die before they are able to bore their way through to the inside of the kernel.

Time of harvesting

Crops should be harvested as quickly as possible to avoid infestation of the grain in the field. A problem with high yielding and early ripening varieties is that the harvest period will be in the wet period. This causes new storage problems.

4.2 Measures in and around the store

Site selection

Selection of a good place for grain storage is very important.

- Grain stores must be built on well-drained ground so that the building or container does not get flooded by ground water run-off during heavy rains or take on too much moisture from the ground.
- The storage should be placed as far away as possible from grain standing in the fields. This helps to protect the grain against insects flying from the field to the storage area.
- The storage should not be built near places where animals are kept. Certain insects found near animals and their food also attack stored grains.

Product selection

The risk of losses is reduced if only clean and healthy grain is retained for long-term storage. This means that you have to carefully select the foods to be stored. Even if the grain looks clean, insects are almost always there to some degree and mould spores are present everywhere. Broken grains, pieces of straw and dirt increase the chance of storage trouble by insects or mould.

Unthreshed products

If undamaged during harvesting and drying, husks or pods offer some protection against insect attack (maize, paddy, beans). Traditional maize varieties often have husks that cover the whole cob. In prolonged storage it is important to select cobs with undamaged husks that cover the whole cob. Unfortunately the husks of improved varieties offer less protection.

Another storage condition is that the moisture content of the kernels inside the unhusked cob should not be too high when put into the storage commodity. If the unhusked cobs are too moist they will soon get mouldy: the husks provide favourable conditions for mould growth. Dry them as well as possible before storing.

Hygiene

To prevent damage to stored products it is essential that thorough hygienic practices are used. Stores, silos, cribs etc. and their immediate surroundings must be kept as clean as possible.

- Before use, every storage facility should first be checked for leaks, splits, cracks, etc. and be repaired if necessary. The floor surface should be easy to sweep. Cleaning is simplified if the corners are filled up with cement and rounded off.
- If possible, the walls of the store should be white-washed first. This paint helps to close up very small holes. Insects like to hide in these small holes.
- The floors should be swept at least once a week. Waste (sweepings, infected produce) must be immediately destroyed. They should never be left in rubbish bins 'for the time being'.
- A new harvest should never be stored with the remainders of a previous harvest. Clean the containers or store before bringing in the grain. Never store products in used bags without washing and, if necessary repairing them. Bags or sacks should be boiled in hot water and dried in the sun. Bags with holes should be mended.

Dry and cool storage

Prevent the absorption of water when the product is stacked. The product can be placed on plastic or on a layer of tar paper. When the product is stored in bags these should preferably be stored on pallets. Pallets can be made of wooden laths or poles (see figure 4).

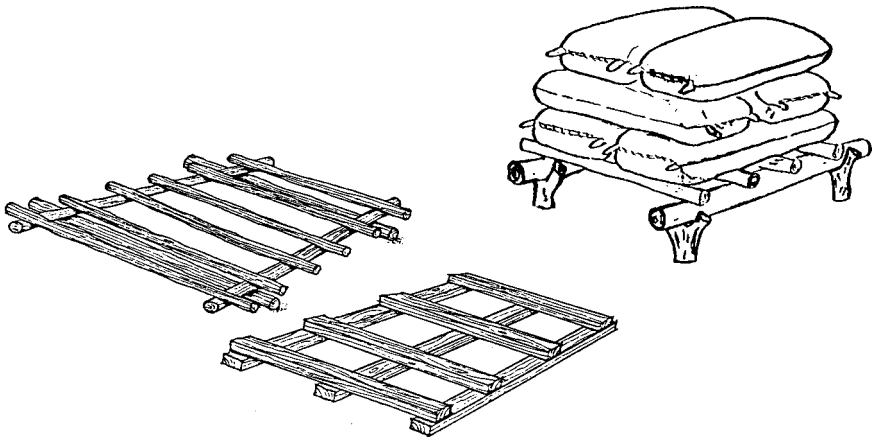
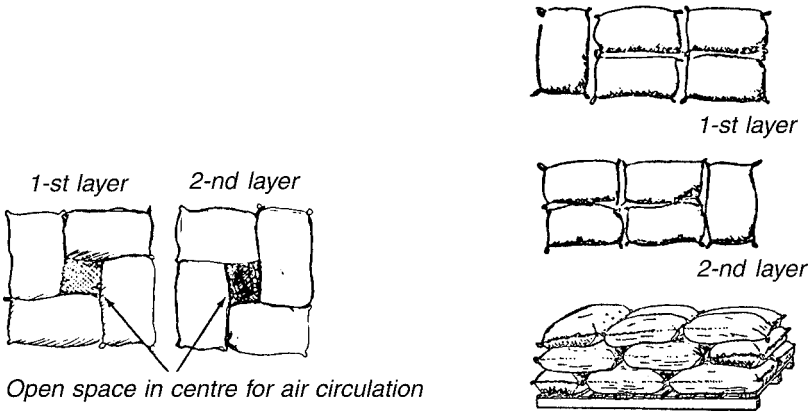


Figure 4: Pallets

The bags should always be neatly stacked, in such a way that air can pass through the sacks to dry and cool the grain. A few examples of patterns to stack bags are shown here.



Odd Layers	Even layers	Bags per layer
		3 per layer
		5 per layer
		8 per layer

Figure 5: stacking patterns for bags on pallets

There should be a space of about 40 cm between the walls and the piles of product to reduce condensation and facilitate inspection and cleaning (see also chapter 7).

Record keeping

Records should be kept by noting the time of storage, the conditions and the control methods adopted in the various sections. The stores must be inspected weekly. It is advisable to appoint one person who will be responsible for the hygiene and management of the storehouse. During storage, the principle to follow is 'first in, first out': the first product to go into the store will be the first one to come out.

4.3 How to handle the stored product

Drying

Drying prevents germination of the seed, the growth of bacteria and mould and it reduces the conditions for development of insects. The moisture content of a stored product is influenced by the humidity of the air. The more moisture in the air, the higher the moisture content of the product. If grains are harvested during warm, humid weather, the moisture content of the grain will be high because the relative humidity of the air is high as well. More information about moisture content and air humidity is given in *Agrodok 31: The Storage of Tropical Agricultural Products*.

Moisture may enter the store from the ground, through the walls and the roof. If humidity outside the storage is high one should make an attempt to reduce exchange of the atmosphere within a grain mass with that of the outside. This might be done through near air-tight storage. Not putting sacks directly on the floor or against the wall may also be of help.

It is necessary to dry the grain before it can be stored safely. The method of drying depends on the local conditions (climate, season, volume of the crop, financial situation of the farmer, available material). Maximum use should be made of sun and wind, and suitable

measures should be taken to see that crops which are dry do not become wet again through dew or rain.

When drying the kernels in the sun one should stir regularly to distribute the heat equally over the bulk. In case of products like maize, millet and sorghum it is possible to let the crop dry in the field, after which the crop will be harvested.
Exposure of grain to the sun by spreading it out on sheets or hard surfaces, causes the adult insects to fly away, as they are unable to stand high temperatures (above 40-44 ^{o}C) or bright light. The eggs and larvae inside the kernel are not necessarily killed by the sun.

Regularly drying the stored product in the sun, will keep the product insect-free and dry. Dry grains are hard to be attacked by fungi.

By artificial drying the temperature can be raised to a much higher degree. Under these conditions it is possible to kill the eggs and larvae inside the kernel as well.

Water absorbing materials

A useful method to dry grain is mixing the grain with water-absorbing materials followed by packing it in air-tight containers. Water absorbing materials one may use include wood ash or straw ash, clay dried in an oven, toasted rice, etc. The added dry material absorbs water from the product with which it is stored.

Temperature regulation

Warm air can hold more moisture (water vapour) than cold air can. When warm air cools down it has to get rid of some water. The surplus water condenses and forms little drops. This is what we call dew. If there are large differences between day and night time temperatures there will be dew on the stored grain every morning. This dew makes the grain wet. The grain will get caked and mouldy, even if it was dry when it was put inside the store or container. If this occurs one should attempt to minimize the temperature fluctuations in the store by shading, insulation or some other method.

Another thing one should know is that at a lower temperature insects and fungi do not grow as fast as at higher temperature. As temperature goes up, fungi and insects grow faster and the grain respires more quickly.
Living creatures like insects, fungi and even kernels of grain do produce heat themselves when they are active in one way or another. Growing, walking, developing, even the development of an embryo inside the kernel are all activities which produce heat. This heat builds up inside the grain and hot spots can form in areas of the grain where most fungi and insect activities are occurring. A hot spot causes insects to spread and condensation of water vapour in cooler areas of the grain (e.g. nearer the surface). Consequently mould growth and sprouting of the grain occur, which results in the formation of new hot spots. In this way the process stimulates itself and the loss of grain increases.
If the grain contains more moisture, this process is even faster.

Air tight storage

Air-tight storage works on the principle that insects will die due to lack of oxygen. An oil drum with a perfect fitting lid can be used as an air-tight storage container. Plastic bags, scooped, well dried pumpkins and very dry underground pits are also useful as air-tight storage.
You can also make your own air-tight container. A woven basket can be smeared with clay to make it air-tight. When your have filled the basket seal it off with a layer of clay. Then insert a burning wick through a small hole. This will use up all the oxygen inside the basket and make it completely air-tight. When the flame goes out remove the wick and cover over the hole.
Mixing the storage product with fine minerals decreases the amount of space between the kernels. Less air and thus less oxygen will be available for the insects. For more information see the section on minerals in Chapter 5.

Conclusion:
A clean, dry and cool store together with clean and dry grain are the first and most important steps to successful storage of grain.

5 Non-chemical insect control

There are many methods to control insects without using chemicals. In general these methods might take more time, but they will cost far less money. Non-chemical control include mechanical methods and adding natural material that have insecticidal or repellent characteristics. There are many natural additives like local plants (or parts of them), minerals or oil, that are useful to control or repel insects damaging stored products. Used in the right way these additives may even have a protective action. In general these methods are only useful in small scale storage.

5.1 Mechanical methods

Sorting

It is possible to remove insects that are present by hand. The grains that have been attacked can be removed at the same time. This is a very accurate but time consuming method.

Sifting and winnowing

A considerable improvement of sorting is sifting. A sieve with a mesh size smaller than that of the grains is used. The insects will pass through the sieve and are collected and destroyed (burned!). A disadvantage of sifting is that attacked grains are not separated from healthy grains.
Winnowing produces the same results as sifting.

5.2 Parts of plants as natural additives or repellants

Before using plants as insecticides or repalents, you must remember that some plants or plant extracts can be poisonous to humans. Just because something is of plant origin does not necessarily mean it is harmless! You must therefore exercise caution when using plants as insecticides (See also Appendix 1).

The usefulness of the various parts of the plant varies according to the type of plant. The insecticidal properties are often stronger in one particular part of the plant. For example, it is known that the external skin of the fruit and the seeds of the red pepper are more effective for killing insects than other parts of the plant.
In many areas local plants are known of which the roots, leaves, flowers, fruits and/or seeds act as a repellent or as an insecticide. For a long list of plants which are used to protect storage products see Appendix 1.

Ask the local people! For sure they will know about plants that are used as an insectice or repellent.

Leaves

The whole dried leaves of certain plants can be mixed with the stored products in a number of cases. However, it is more common to make a powder from leaves which is then mixed with the stored product. The effectiveness of this method of protection depends not only on the type of the plant and quantity used but also on the circumstances under which the plant is cultivated and the time at which it is harvested.

In Burkina Faso, for example, the unbroken leaves of Hyptis spicigera or Cassia nigricans are layered with the pulses which are to be stored, to protect the product against the bean weevil.

The amount needed to protect the product varies from plant to plant. In general the amount of plant material must be determined by trial and error.

As little as 3 g of the dried and powdered leaves of **Hyptis spicigera or Cassia nigricans** is sufficient to protect 1 kg of pulses against bean weevil (a concentration therefore of 0.3%).

Powder made from the leaves of **Persian lilac** protects against grain weevil. It should be used in a concentration of 40-80 g of powder for every 1 kg of product (a concentration of 4-8%).

Twigs

In a number of cases not only leaves but whole twigs are used to protect against insects. See the example of the twigs of the muna-bush in the box.

There are variations on basic local methods according to local uses, store size, etc. Taking the use of twigs of the muna-bush for example, some farmers construct a simple silo of earth which has a small door at one side through which the potatoes can be taken out. The interior is lined with muna and chillihua and the silo is then filled through the open top and covered with muna twigs and a good layer of straw. Finally a layer of clay about 3 cm thick is smoothed over the surface to keep out the rain.

In Latin America the twigs of the muna-bush (found only in Latin America) are used to protect stored potatoes against the potato tube moth. The walls and floors of the store are covered with muna-twigs before the potatoes are deposited. Once the storage space is full the potatoes themselves are covered with a layer of twigs.

Seeds

Certain seeds also serve as an insecticife or repellent. They can be ground and used as powder or it is also possible to press oil out of them and use this as an insecticide.

Preparation of Neem oil - a successful insecticide

Seeds of the neem tree can be used as a powder or as an oil. To produce neem oil by hand, use the dried kernels. These have to be decorticated first. They are crushed in a mortar, so that the outer husks are freed from the inner seed. The shells are removed by winnowing. The decorticated kernels are thenpounded in the mortar until they form a brown, slightly sticky mass. A little water is added so as to form a workable paste which forms an almost solid ball. This ball is kneaded for several minutes over a bowl until oil collects on the surface of the ball. It is then pressed firmly, and oil will come out in drops. Alternate kneading and squeezing will separate the oil.
With this method 100 - 150 ml of oil can be extracted from 1 kg of neem kernels. This is about half the oil content. If machines are available these can also be used for oil extraction. Heating of oil is said not to effect the insecticidal properties.

Another example in which seeds are used is the use of sunn hemp seeds. These seeds are used to keep weevils from stored rice and maize.

Sunn hemp seeds are spread over the ground and bags are put on top of the seeds. This procedure is continued, layering sunn hemp seeds and bags of stored grain. After about 9 months the process must be repeated.

Rhizomes

A rhizome is the thick horizontal stem of some plants, just on the soil surface or just in the soil, from which new roots grow and new plants grow. Often rhizomes keeps plants connected to each other for a while (figure 6).
Only some plant species have rhizomes and few of those have insecticidal properties. An example of a plant with a rhizome with insecticidal properties is sweet flag.

Figure 6: Sweet flag - a plant with a rhizome

Sweet flag

Sweet flag is native to India but has achieved worldwide distribution because of its high medical value. It will grow at altitudes of up to 2000 metres. At these elevations production of essential oil is greatest.

Turmeric is another example of a plant of which the rhizome has insecticidal properties. 20 g of dried pulverised rhizome added to 1 kg of stored product has been found to be highly repellent against Grain weevils and the Lesser grain borer.

Rhizomes can be used as a powder or as an oil. To preparing the powder the rhizomes are dried after which they can be pulverised. To prepare oil the same method as described for neem seeds can be used.

5.3 Minerals as additives

Minerals like fine sand, lime, certain types of kaolin clay and ash can be used to protect stored grain against insects.

Filling the space in between the grains

The minerals are mixed with the threshed grain, they will fill the spaces between the grain kernels and thus prevent movement and dispersal of insects inside the stored grain. Damage will not be totally prevented but newly hatched weevils are hindered in their activities. They experience more difficulty in finding others in order to multiply- and they are also forced to deposit their entire stock of eggs on relatively few grain kernels or beans.

Filling the space in between the grains with fine material is a traditional method to remove oxygen from the stored product. In this way there is less air mixed with the stored product making it hard for insects to get enough oxygen to live. See also the section 'Air-tight storage' in 4.3. A similar method is mixing cereal with small grains (for example millet), with maize or sorghum.

Activated clay or charcoal

Particularly effective in this case is the use of activated clay or charcoal. These materials absorb oxygen from the air and thus remove even more oxygen.

Activated clay or charcoal can be made as follows:

- wash small pieces of clay or charcoal in diluted hydrochloric acid (HCl) or sulphuric acid (H_2S)
  Careful! Acids are agressive!;
- rinse them with clean water;
- let the pieces dry;

The amount of activated clay or charcoal needed will be about 0.5 to 1.0 % of the total amount of grain that has to be treated.

Scratching the skin of the insect

There are some other effects which make minerals quite useful. Sand scratches the outer skin of the insect. The damaged skin does not protect the insect any longer against water loss. If the grain is dry the in-

sect will not be able to replace the water loss and it will die by drying out.

Amount of minerals needed

The amount of minerals needed depends on the circumstances and the type of mineral:

- Sand is effective when 1 kg of sand is mixed with 10 kg of product.
- Ash is claimed to protect the stored product when 1 kg of ash is mixed with 40 kg of product.
- For clay 1 kg is recommended to protect 10 kg of product.

These figures are only guidelines. *The real amount should be determined by your own experience!*

Locally available mineral dust should be tested for suitability. For example, grain weevils seem to be extremely sensitive to hard, abrasive mineral dusts like quartz. Rice weevils on the other hand are extremely sensitive to activated coal, heat-activated clay dust and the ashes of rice husks.

Using minerals to protect the grain you have to take care to use only extremely dry minerals. Moist minerals add water to your storage product and as you have seen before moisture may stimulate the development of fungi.

Storage protection of maize and beans in Kenya

In Kenya maize and beans are treated in the following way. The product is dried well and packed into sacks, mixed with ash (for example from the cooking fire). Every 4 months the sacks are opened and new ash is added, as the ash gradually sinks to the bottom of the sack. In this way maize and beans can be stored for up to 5 years. In many cases ash has proved more effective than malathion 2 %.

5.4 Oil as an additive

Numerous vegetable oils can be used as a protective additive. An advan-tage is that they are easy to apply. usef with success in practice are the oils of peanuts, coconuts, safflower, mustard, castor beans, cotton seeds, soya beans, neem and maize. Not all types of oil will be effective. Sunflower seed oil for example is not effective in all cases.

The oil is mixed with the product. Use only small amounts of oil (for instance: 2-4 ml per kg threshed beans) and mix the oil and the product thoroughly. This is best done in a big pot or something similar, and portion by portion. After treatment the product can be stored in sacks.

Oil can be used preventively as well as curatively.

Protective action

Because of the oily coating of the seeds, the insects are unable to reproduce. They fail to lay eggs in the kernel. Larvae outside the kernel are not able to enter the kernel either because of the slippery oil coating.

The mechanism how oil protects the seeds is not completely clear, but it appears that vegetable oils effect egg laying as well as embryo and larvae development on the surface of the seed. Vegetable oils cause the eggs and larvae to die before they can bore into the seed.

If the larvae do manage to penetrate into the seed, because it has not been sufficiently coated with oil, then the treatment produces no further effect and the larvae will develop normally. In some cases female insects are able to lay eggs, but the hatching of the larvae is prevented by the oil.

Curative action

Oil may also kill the insect eggs. When the egg is already present at the surface of the seed or inside the seed, the oil coating prevents gaseous exchanges. So the larvae inside the egg or the kernel will die due to lack of oxygen.

Some oils such as those derived from neem, karanja, undi and kusum also have an insecticidal effect. A small amount of oil from neem, karanja and kusum added to the storage product may kill about 90 % of the Cowpea weevil. The protective effect may last for about 3 months. Ensure yourself that the oil won't be harmful to human beings!

Oil can be an effective protection or cure against insect damage. It is important to mix the oil very carefully with the grain or beans. If a small piece of the kernel is not coated by the oil, the adult insect can lay its eggs and larvae may enter the kernel.

Table 2: Some examples of oils used for storage protection

Storage product	Type of oil	Amount of oil	Effect
Cowpea	Peanut oil	5 ml/kg	Peanut oil protects the cowpeas against the Cowpea weevil infestation for about 6 months.
Mung beans	Cotton seed oil	6 ml/kg	After 6 months only 3.5 % of the seeds were damaged.
Mung beans	Rice husk oil	5 ml/kg	Prevents against damage for about 4 months.
Cowpea, Maize	Denettia oil	1 ml/kg	Denettia oil protects cowpea against Cowpea weevil for more than 3 months. Maize is also protected for a period of 3 months, even when only 2/3 of the given amount of oil is added.
Beans	Neem oil	2-3 ml/kg	If well mixed this amount of neem oil protects the beans for about 6 months. Neem oil has an insecti-cidal effect as well. For preparation of neem oil see 5.2.

Disadvantages of the use of oil

There are also some disadvantages to the use of oil:

- Oil can have a adverse effect on the germination power of the oil-treated seeds. Therefore it is recommended that seed which is intended for sowing should not be treated with oil.
- Oils can also be poisonous to human beings. Cereals that are intended for food should only be treated with vegetable oils.

- Locally made oil may go rancid which will then make the product taste unpleasant.

5.5 Smoke and other appliances

Smoke

With the help of smoke and heat from an ordinary fire, insects can either be killed or be chased. It has some additional effects as well. It will dry the grain further and will protect the grain against reinfestation. Smoking can be done for example above the cooking place.

Other appliances

In southern Togo traditional maize silos are sprayed with goats' dung solution. Probably the strong smell deters insect pests as well as the goats themselves from attempting to enter the store.

In Appendix 1 you find an extensive list of additives used in traditional storage protection.

6 The use of insecticides

There are many different insecticides that kill insects. Only few can be used to control storage pest insects because there are strict regulations on the use of pesticides on or near foodstuffs. Insecticides that need a long time to degrade and as such leave residues in the product are unsuitable for use on stored produce. The residues of chemicals cause health problems when eaten by human beings or livestock.

Using insectides is a waste of money and effort, when good storage practices are not implemend. These good storage practices and non-chemical practices, such as sanitation, drying of the produce and physical precautions have been described in Chapter 4 and 5. Only when these precautions and the proven traditional practices for pest control have been implemented but can't control the storage pests satisfactorily, then pesticides should be used as an extra practice. Implementing an integrated approach by combining the advantages of the different practices will give a better result with less frequent applications.

Extension services, supported by traders, too often and too easily advice farmers to apply pesticides. People are made to think that using pesticides is a 'modern' practice, but for small-scale storage the disadvantages of the use of insecticides (costs and health hazards) outweigh the advantages.

6.1 Warning!

Before explaining about the type of insecticides and how to apply them, we prefer to give you a warning about the risks of using of pesticides:

Insecticides are toxic

Not one single pesticide is safe. This is a rule that you should always keep in mind when using any type of pesticide. Insecticides are poi-

sons for killing insects and they can be very dangerous for human beings as well as for domestic animals like cows, poultry, fish, dogs, cats, etc. Some insecticides even poison the grains, this is especially important when seeds for planting are stored.
Advertisements proclaiming an insecticide to be safe or not toxic should always be taken with a large pinch of salt. Of course, some insecticides are less hazardous than others, but when not used in the correct way any insecticide may become very dangerous.

6.2 Effective and safe use of insecticides

Below we give a list of directions how to use insecticides effectively and safely. Please, pay attention to these points before using pesticides.

How to use insecticides *effectively*:

- Only use insecticides on stored products which are clean and dry and in good storage conditions, otherwise you waste your money.
- Find out which insecticide to use under specific circumstances or against specific pests. Not all the insecticides available are suitable:
  - Some insecticides can be used on seeds for planting, but cannot be used on grains for food, because the residue is toxic to humans.
  - Some insecticides cannot be used in combination with certain materials. E.g. malathion should not be used or put in metal containers.
  - Some insects have developed resistance against certain insecticides.
- If you are not certain which insecticide you can use, ask your extension agent.
- Know that quantities and timing of application are often critical for a successful result.

How to use insecticides *safely*

- Never buy or use an insecticide without a label on the container, that tells you which insecticide is in the package. A label is also

necessary to tell you the concentration of the insecticide, how to apply the insecticide and which precautions for safety you should take.

- Make sure the mixture is correct for its purpose. Using a wrong insecticide can poison the stored produce.
- Follow the directions for use very strictly. *If there are no directions, do not use the poison!*
- Do not use more than the recommended dose.
- Know how to apply the insecticide properly. Can the poison be used directly on the grain or do you have to spray it around the grain storage areas or on the outside of the containers? Do you have to dilute the chemical? Do you have to use it as a dust or do you have to make a solution?
- Wear protective clothing to avoid coming into contact with the insecticide. Avoid inhaling dusting powders, gases or fine droplets by wearing a mask. Liquid insecticides and to a lesser extent powders can be absorbed through the skin. Avoid contact with the skin by wearing gloves, a shirt with long sleeves, trousers and shoes.
- Destroy empty containers. It them is very dangerous to reuse them.
- Wash your hands and clothes after using insecticides.
- Do not eat, drink, or smoke while using poison.
- Keep poison containers as well as application equipment away from children and animals.
- Return waste chemicals to the agricultural field station in your area. Do not throw them away or pour them into a river or anywhere else. Poisons, including insecticides as well, are very dangerous for people, for insects, for domestic animals, for fish, for plants and for any other living creature coming into contact with the poison.

See also Agrodok no. 29: *Pesticides: compounds, use and hazards.*

Preference should be given to non-chemical practices for protection of stored products because there is no problem with resisdues of the chemical in the stored foodstuffs. Also health hazards are avoided when chemicals are not used.

6.3 How to apply insecticides

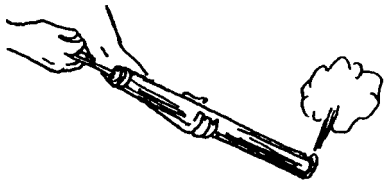
There are two major ways to apply insecticides in order to control storage pests:

- Mixing insecticide with the grain; the insect is killed when it gets in direct contact with the poison. These insecticides are called 'Contact chemicals'. Contact chemicals can be applied in several forms: Dusts, wettabble powders and emulsion concentrates.
- Fumigation, which means that the insecticide is gaseous and as such it can penetrate the stored product. Insects are killed when they inhale the poisonous gas. Insecticides used for fumigation are called 'Fumigants'.

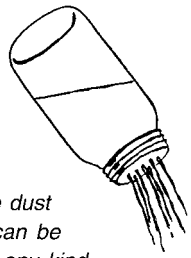
Below, the contact chemicals and the fumigants are elaborated.

Dusts

Dusts are a mixture of insecticide with powder. Dusts contain a low concentration of insecticide. You buy them ready for use and they are easy to apply. Dusts are mixed with the stored product at the time of storage. They must be well mixed in and therefore they must be kept very dry otherwise they will not mix evenly. Another reason for keeping them dry is that moist makes the insecticides breaking down more rapidly and thus the insecticide will not be effective for very long. In stead of being mixed with the stored product, dusts can also be used on floors, around the bottom of storage containers.



A: A plunger-type duster is like a small hand pump.



B: A simple dust applicator can be made from any kind of container which has a lid that can be screwed back on. Punch holes in the lid for the dust to come out.

Figure 7: Application equipment for dusts

Mixing dusts with the produce

Dusts are mixed with the stored product at the time of storage. We explain three ways to mix the dust well with the product.

Door for filling and emptying the drum

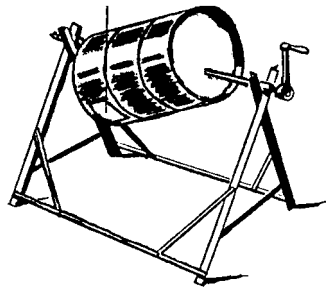


Figure 8: Hand machine for mixing

1 Using a drum that is made into a hand machine for mixing. You can mix only small portions at the time, but mixing is done thoroughly and the person doing the mixing has not that much direct contact with the insecticide - if the drum can be closed off well.
Grains and insecticide are both put in the drum, which then is turned round may times. When the mixture comes out, you should not see any patches of powder.

2. Mixing insecticidal dust using a shovel (figure 9)

a. Empty the bag of grain onto the floor in a heap and sprinkle the correct amount of insecticidal powder over the heap.

b + c. Shovel the heap onto another part of the floor then shovel it back again.

d. When you have finished, you should not be able to see any patches of insecticidal powder

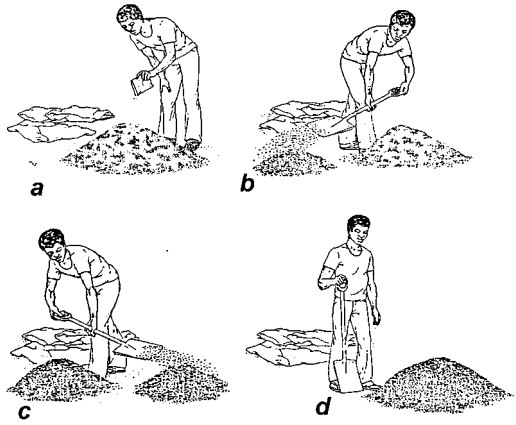


Figure 9: Mixing insecticidal dust using a shovel

3 Mixing insecticidal dust with corn-cobs to be stored (figure 10)

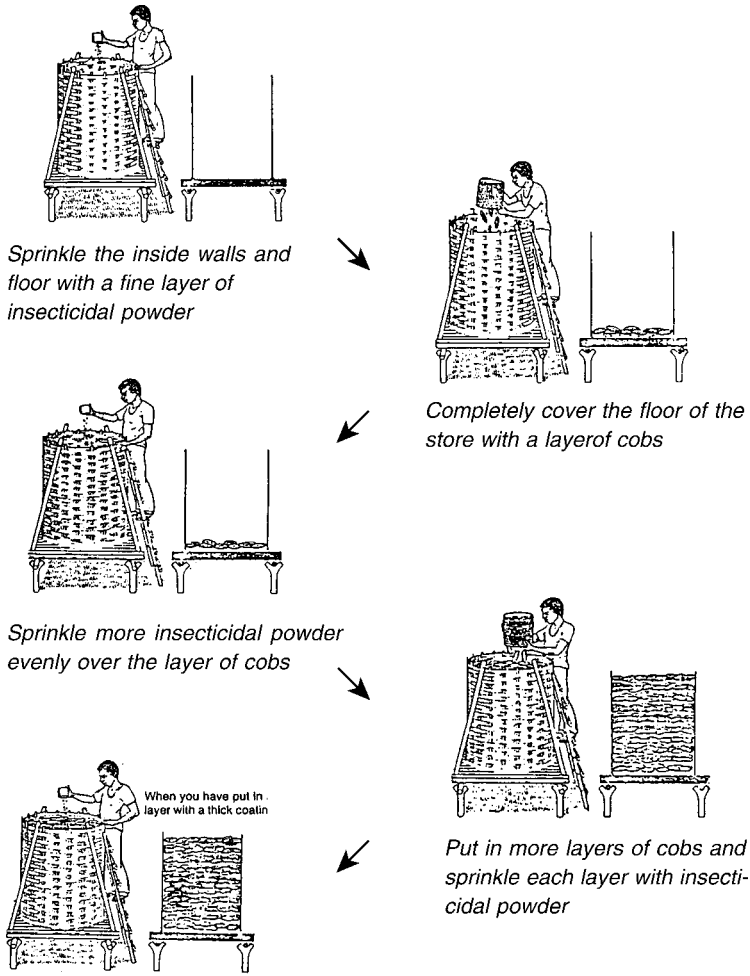


Figure 10: Mixing insecticidal dust with corn-cobs to be stored

WARNING: use only those dusts recommended for the purpose! e.g. malathion or pirimiphos methyl.

Wettable powders

Wettable powders contain a high concentration of insecticide. They must be mixed with a certain amount of water before they can be used. Becaus e of the high concentration mixing should be done very carefully! Wettable powders are used to spray outside surfaces of sacks of grain, storage containers or buildings. *They should never be used directly on the grain.* Wettable powders can be applied with simple sprayers which can be made by yourself or purchased.

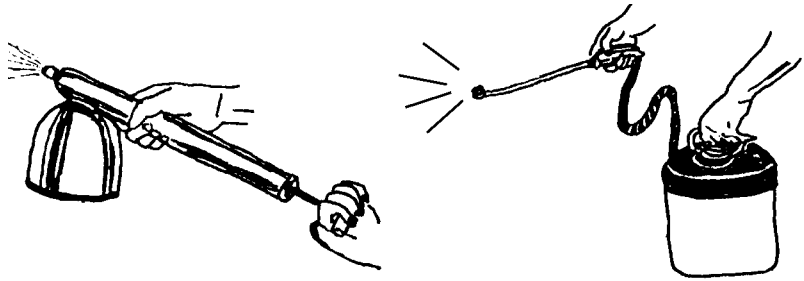


Figure 11: Some examples of application equipement for wettable powders

Emulsion concentrates

Emulsion concentrates are bought as liquid concentrates which contain a high amount of insecticide. Special equipment is needed to apply these emulsions. This means that this form is more expensive and more difficult for small-scale farmers to use.

Fumigants

Fumigants are gases and are, therefore, self-dispersing and non-persistent. They have several advantages over contact poisons due to their ability to penetrate into a mass of grains and not leaving residues:

- if applied properly, fumigants penetrate the whole batch of product evenly and kill the insects;
- in most cases gas can even kill larval stages inside the kernels;
- gas leaves no marks on the grain as some insecticides do, though fumigants may damage the ability of seeds to germinate;
- gas does not leave residues in the product.

If used in a larer storage building:

- gas can enter all the cracks in storage buildings thus killing insects hiding there;
- gas can get between the tightly packed grains in storage and kill the insects living there;

Fumigants kill only insects which are already in the grain. They do not protect grain from new attacks because there are no residues.

Fumigants in general have a better effect than the contact chemicals. But it can only be applied when it is possibe to achieve gas-tight conditions in the storage building or in containers.

Covering the grain sacks with a heavy plastic sheet and closing that tightly will also do.

> The greatest disadvantage of fumigants is that they are ***very dangerous to human beings!*** Therefore fumigants should always be handled with greatest care by trained personnel, wearing protective clothing. At least two operators must be employed in fumigating infested products for safety reasons. *Never use* fumigants yourself as long as you are not trained in using them!

6.4 Insecticides used for controlling storage pests

As mentioned before, many insecticides are available but only few can be used for protection of stored cereals and pulses. Below we describe a few insecticides which are commonly used. When we describe toxicity, we mention if the insecticife is toxic for human beings and warm blooded animals. Care should b etaken thoughthat fish often are far more sensitive to these poisons and bees are insects too.....

Choosing an insecticide to your choice is not always possible, your choice is limited by the availability of insecticides. When you buy an insecticide always make sure the container has a label with instructions for application! Be aware that pesticides can have different trade

names. Below we name the active ingredients, these should always be mentioned on the label.

Malathion

Malathion may be mixed with grain as a dust or sprayed on walls or floors. As a dust it is one of the insecticides most widely used to protect stored cereals and pulses. The product to be dusted must be well dried, otherwise malathion breaks down very rapidly. Malathion is not suitable for disinfecting storage structures because it is unstable on concrete surfaces or whitewashed walls.
Between treatment and consumption there should be a period of 12-13 weeks. In that period malathion breaks down completely without leaving harmful residues. Some disadvantages of malathion are:

- malathion is not very effective against the lesser grain borer;
- some insects have already developed resistance against malathion. This means that the insecticide is no longer killing these insects;
- malathion has a nasty smell;
- malathion is only slightly effective against caterpillars, moths and mites.

Recommendations for use of malathion dust

- Shelled maize /rice: 1000 g of malathion 1% dust / 1000 kg of cereal
- Threshed beans: 1000 g of malathion 1% dust / 1000 kg of beans
- Corn-cobs: 1000-1500 g of malathion 2% dust / 1000 kg of cobs

Pirimiphos-methyl

Pirimiphos-methyl has a low toxicity for humans and warm-blooded animals. It remains stable, even on relatively wet grain. It is persistent for several months which reduces the risk of reinfestation by a second generation insects or new ones from outside.
Pirimiphos-methyl is active against beetles, moths and mites. It performs well against species resistant to malathion.

Pirimiphos-methyl is available in different formulations: dusts, wettable powder, emulsion concentrates and fumigants. Trade names are: Actellic, Actellifog Silosan, Blex.

Recommendations for use of Pirimiphos-methyl dust

- Shelled maize/rice/beans: mix 200-500 g of 2% dust /1000 kg produce.

Pirimiphos-methyl can also be used to disinfect stores before the product is entered or to treat a stack of bags while being built. For these applications, read the instructions on the labels of the containers.

Bromophos

Bromophos has a relative low toxicity (similar to malathion) for human beings and their domestic animals. It is more persistent than malathion on concrete surfaces and therefore it can be used for disinfection of storage buildings. It is also more persistent on warm moist grain.
Residues of Bromophos are easily destroyed by heating (cooking or baking) the cereals in the preparation of food.

A disadvantage is that Bromophos acts slowly: the adult insect may lay its eggs before it is killed.

Bromophos is available as a dust, to mix with the stored product, or as a emulsion concentrate to treat stacks of bags or walls and floors.

Recommendations for use of Bromophos dust

- Grain: mix 10-20 g of active ingredient / 1000 kg produce.
- Maize or beans: mix 8-12 g of active ingredient / 1000 kg produce.

Chlorpyrifos methyl

Chlorpyrifos methyl has a relative low toxicity for human beings and their domestic animals. It is effective against a wide range of storage pests except against the resistant Lesser Grain Borer. Mixing Chlorpyrifos methyl with Bioresmethrin (see section further down) could

make a very effective mixture against many species. The trade name of Chlorpyrifos methyl is Reldan.

Recommendations for use of Chlorpyrifos methyl dust

- Grain: mix 2.5 - 4 g of active ingredient / 1000 kg produce.

Be sure that the insecticide you use is Chlorpyrifos methyl and not Chlorpyrifos(-ethyl). They are not the same and the latter is far more toxic!

Fenitrothion

Fenitrothion is very effective against a wide range of insect pests, although it is not fully effective against the Lesser Grain Borer. It can be used to disinfect storage structures or to protect stored produce. It is more persistent than malathion. Mixing Bioresmethrin (see further down) with Fenitrothion could make a very effective mixture against many species. Fenitrothion is far more toxic for human beings and their domestic animals than the insecticides described before. But because it hardly penetrate into the grains, most of the residues are removed when dehusking when milling.
Trade names are: Sumithion and Folithion. It is available as dust, emulsion concentrate and wettable powder.

Recommendations for use of Fenitrothion dust

- Grain: mix 4 - 12 g of active ingredient / 1000 kg produce.
- Corn-cobs: apply 8-20 g of active ingredient / 1000 kg produce.

Methacrifos

Similar to Fenitrothion, Methacrifos is far more toxic for human beings and their domestic animals than the other insecticides described before. Methacrifos is useful in cases where insects are building up resistance against malathion (Maize-, Rice- and Grain weevil and the flour beetles). Special characteristic of Methacrifos is that it penetrates into the grains, thus killing larvae inside the kernels.

Methacrifos works very well at lower temperatures. Its tradename is Damfin and it is available as emulsion concentrate and a 2% dust.

Recommendations for use of Methacrifos dust

- Grain: mix 10 - 15 g active ingredient / 1000 kg produce.

Bioresmethrin

Bioresmethrin is a synthetic pyrethroid and it has a very low toxicity for humans and animals. It acts mainly as a contact insecticide but inhalation and ingestion are also lethal for insects. Bioresmethrin deteriorates rapidly when exposed to light.

Bioresmethrin is effective against the Lesser Grain Borer, so it is especially useful in situations where the Lesser Grain Borer has developed resistance against insecticides such as Malathion, Pirimiphos-methyl, Fenitrothion and Chlorpyrifos-methyl. In these cases Bioresmethrin can be mixed with these other insecticides to improve efficiency of the application.

Recommendations for use of Bioresmethrin

- Mix 4 g active ingredient of Bioresmethrin + 20 g of active ingredient of Piperonyl-butoxide to treat 1000 kg produce.
- Mix 1 g of active ingredient of Bioresmethrin + 12 g active ingredient of Fenitrothion to treat 1000 kg produce (especially to control those insects that are developing resistance against Malathion).

Deltamethrin

Deltamethrin is similar to Bioresmethrin, also is a synthetic pyrethroid, and has a very low toxicity for humans and animals. However, the formulation of Deltamethrin solved in vegetable oil has a dangerously high toxicity. Deltamethrin is stable on the grain for a long time, but because it does not penetrate the grains, it is removed when dehusking.

Deltamethrin is very effective against the lesser grain borer which is not very susceptible to Malathion, Pirimiphos-methyl, Fenitrothion

and Chlorpyrifos-methyl. It also is very effective against the grain weevil (Sitophillus granarius).

Recommendations for use of Deltamethrin

- Corn-cobs: for long term storage, apply 1 g active ingredient of Deltamethrin wettable powder to 1000 kg of dehusked corn cobs.
- Pulses: Apply 0.75 g active ingredient of Deltamethrin to 1000 kg of pulses. This is an effective protection against the cowpea (or pulse) weevil and the adzuki bean weevil.
- Grain: Apply 1 g active ingredient of Deltamethrin + 4 g active ingredient Piperonyl-butoxide per 1000 kg of grain.

Permethrin

Permethrin also is a synthetic pyrethroid. It has a very low toxicity to human beings and animals (except for fish). When solved in oil its toxicity is much higher however. Permethrin is effective against a large range of insects and especially against the Lesser grain borer. It has little effect against flour beetles though. It is very persistent on grain and not very sensitive to moisture.
Because Permethrin is effective against the Lesser grain borer, it is often mixed with Malathion, Pirimiphos-methyl, Fenitrothion and Chlorpyrifos-methyl, in cases where the Lesser Grain Borer has developed resistance. The efficiency of Permethrin (and other synthetic pyrethroids) is improved by adding Piperonyl -butoxide.
Permethrin is especially important also for the control of the Larger grain borer, these two grain borers are of the same family which is very sensitive to synthetic pyrethroids.

Permethrin is available as dust (0.5 %) which is a useful formulation. For the protection against the Larger Grain Borer it seems more effective to store and treat shelled maize in stead of maize on the cob.

Recommendations for use of Permethrin

- Grain: apply 1-2 g active ingredient of Permethrin + 10 g active ingredient of Piperonyl butoxide + 4-6 g active ingredient of

Pirimiphos-methyl per 1000 kg grain, for a protection of at least 9 months.

Effective application for protection against the Larger Grain Borer

- Shelled maize: 2.5 - 5 g active ingredient of Permethrin per 1000 kg of maize.
- Shelled maize: 1 g active ingredient of Permethrin + 4 g active ingredient of Pirimiphos-methyl per 1000 kg of produde.

Pyrethrum

Pyrethrum is a botanical insecticide with a low toxicity to human beings and the domestic animals. It has a rapid effect on a wide range of insects, but sometimes after treatment insects can recover. To avoid this Pyrethrum is often mixed with another insecticide, especially Piperonyl-butoxide. The mixture also is cheaper because a lower doses of Pyrethrum can be used (Pyrethrum is expensive).

Pyrethrum is available as oil solutions and solution concentrates. Wettable powders and dusts have a short shelf-life.

Recommendations for use of Pyrethrum

- 1.5 - 2.5 g active ingredient of Pyrethrum + 7.5 - 12.5 g active ingredient of Piperonyl butoxide per 1000 kg grain (ratio of Pyrethrum : Piperonyl butoxide = 1:5)

Bioresmethrin, Deltamethrin, Permethrin and Pyrethrum are all very toxic for fish and other water organisms.

Methoprene

Methoprene is effective against a wide range of storage pests. It has a very low toxicity against human beings and warm-blooded animals. It is effective against the Lesser grain borer, but the Grain-, Rice- and Maize weevil are less sensitive to Methoprene. Methoprene does not directly kill the insects, but it inhibits the reproduction. In this way it prevents development of large populations.

Recommendations for use of Methoprene

- 5-10 g active ingredient of Methoprene per 1000 kg stored product.

Carbaryl

Carbaryl is not effective against storage pests in general, but it is effective against the Lesser grain borer, as such it is used in combination with Malathion, Pirimiphos-methyl, Fenitrothion and Chlorpyrifos-methyl, in cases where the Lesser Grain Borer has developed resistance. Carbaryl should only be used in combination with these insecticides.
Care should be taken because Carbaryl is quite toxic.

Recommendations for use of Carbaryl:

- 5 g active ingredient of Pirimiphos-methyl + 5 g active ingredient of Carbaryl per 1000 kg stored product (protection for > 6 months).

Dichlorvos

Dichlorvos - better known under the trade names DDVP, Dedevap, Nuvan or Vapona - is highly toxic to human beings and warm-blooded animals. It vapourises rapidly and the vapour is very effective against insects. However Dichlorvos is not suitable to use as a fumigant, because the vapour is too volatile. Dichlorvos is therefore mainly used to treat the free space in a store or to disinfect infested grain when brought into the store.

Because of the high toxicity of Dichlorvos, we recommend not to use it.

Lindane

Though lindane is still available, we recommend not to use it. Lindane is highly toxic for humans and animals as well it is very persistent. Residues build up in the food chain and have been traced in milk and meat. As such a there is a danger of chronic poisoning that occurs with long term use. In Europe the use of Lindane is prohibited due to the danger of the residues.

DDT

DDT is still easily available. Many people think that they can use DDT in any situation against any problem. Unfortunately DDT is not as harmless to humans and other warm-blooded animals as many people think. DDT has no direct toxic effect on human beings or animals, but even small quantities of DDT accumulate in the body. Over a longer period of time the accumulated DDT has proven to be toxic to man and animals. Residues have been found in mother milk. Therefore you should **never** let DDT come into contact with food products or animal feed. Neither should it be used for treating the external surfaces of bags containing food products, nor for treatment of the insides of containers for food products or animal feed or in any situation.
In Europe DDT has been prohibited for any use.

7 Prevention and control of rats and mice

Prevention of rats and mice is better than cure. The principle of protective measures is to prevent them from having access to food and water and from making nests. Cleanliness and tidiness in and outside the store are keywords in the prevention of rodents.

7.1 Physical measures against rodents

Hygiene

Keep the farm and storage area as clean as possible. This means:

- Do not pile food or trash around the outside or inside of farm buildings.
- Burn all garbage and old food, at a distance from the house or storage.
- Place all food items in covered containers.
- Store the sacks with produce off the floor.
- Sweep out all dirt, dust, spilled food, straw, old cloth that rodents nest and hide in and burn it immediately.
- Cover mud floors in storage buildings with a thin layer of mortar, if possible. This keeps rats from digging up through the floors.
- Keep the grass cut short around all farm buildings. Rodents like to hide in tall grasses.
- Cut any branches of trees that touch windows to keep rats from climbing the trees and jumping in through the windows.
- Level surrounding grounds. This hampers the digging of holes and provides less cover.

Rodent-proofing

You should make the storage building rodent-proof. This means that the farmer has to construct the granary or store in such a way that rats and mice either cannot get in or have to work very hard to do so.

When making a store rodent free you must take into account all the ways in which the rodents can get into a storehouse. They dig, jump and gnaw. The measures listed below are only a small sample of the numerous possibilities. You must decide according to the particular circumstances which measures will be the most effective. In general it is cheaper to include rodent-protective measures during construction of a store rather than making provisions later.

- Drying platforms (to dry the product before storage) should be placed at least 80 cm above the ground because rats can jump. Put barriers around the poles of the platforms so that the rodents can not climb the poles. These barriers are called rat baffles or rat guards and made of metal sheet or empty tins.

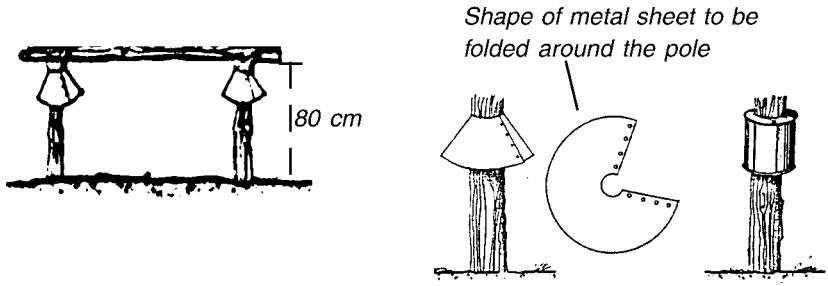


Figure 12: Drying platform and rat baffles or rat guards around the poles.

- Build stores on a concrete base with poles of at least 50 cm above the ground.
  As explained above, farmers should place rat baffles around the poles of mud or cement silos to prevent rodents from climbing or gnawing. If a store is a made of mud blocks use fired bricks at the bottom levels because rodents cannot gnaw through them.
- Make sure doors and grain outlets close tightly. A wooden door should have a thick metal sheet along the bottom to stop rodents from eating through. Grain outlets are sometimes packed with mud.
- Cover all windows and large openings with heavy wire netting. Wire netting with an 8 mm mesh is a good size.

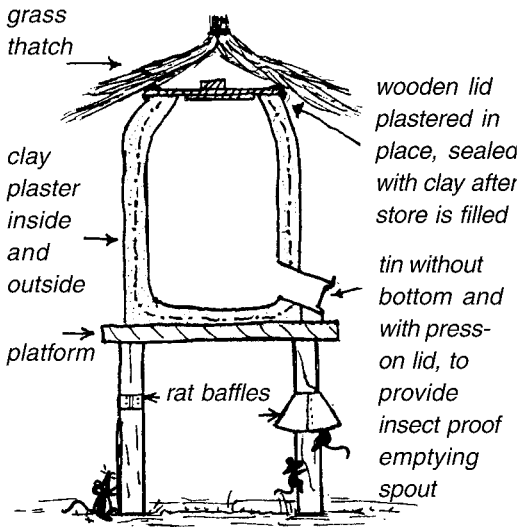


Figure 13: Rodent proof small-scale store

- Cracks in the buildings must be repaired with cement.
- The space between the ceiling and roof must be closed off, but at the same time should be accessible for inspection.
- Rodents must be prevented from climbing along the posts, pipes, cables and rails in and on the building. Fit baffles to all these possible means of access.

As soon as rodents are definitely found to be present, you must:
- identify the species; control of the rodents depend on the species, its habits and behaviour (see table 1 in Chapter 3);
- carefully locate all the pathways the rodents usually take; the place where the animals have penetrated the store should also be located;
- locate the nesting points in the ground or in the building.

Without knowing the species or without knowing its pathways and/or the hiding places control measures will not be very effective. See also table 1.

Setting traps

Regular trapping is a very effective method to catch rodents. Traps are much safer to use near stored grains than poison. In general poisons for rodents are very toxic for human beings and domestic animals, they could be transferred by the rats to the stored product. Traps can be very effective if correctly used and placed:

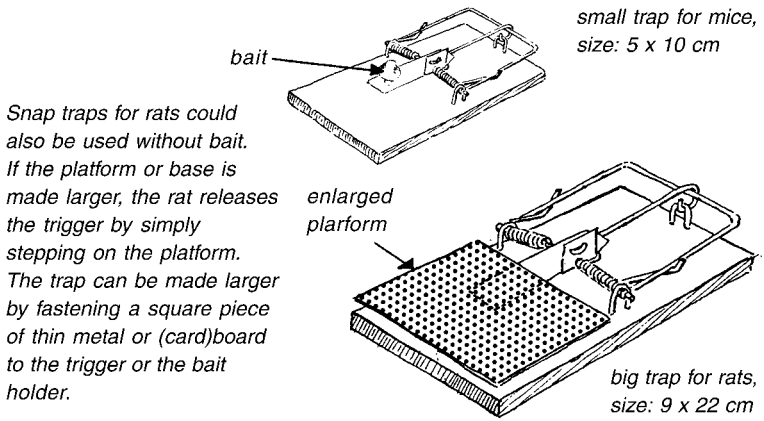


Figure 14: Snap traps for mice and rats

- *Rats or mice*
  Identify carefully if you have mice or rats in your store (use table 1). Put mouse traps for mice and rat traps for rats. Mice traps are not fit to catch rats and the other way round.
- *Baits*
  Baits can be used to encourage the rodents to come to the trap. A bait can be of any food rats and mice like. It should be fixed very well; if not, the rat will steal the bait and run away. A peanut paste, for example, can be very effective. Food bait should be renewed every third day as rats do not like old food.
- *Right place*
  Traps should be put in places where rats or mice normally pass. When a rodent is leaving its nest to eat grain from the storage it will run close to walls or stacks. It will stay out of sight as much as possible. This means that traps should be placed close to the walls and

at right angles to the wall. The trigger end should be nearest the wall so that the trap will attract a rodent running from either direction.

- The brown rat always takes the same way from its nest to the food. Therefore locate the rodents runways and put traps very near to these tracks.
- Traps for black rats and mice should be placed on shelves, beams, pipes and other high places.
- Traps can also be put near holes, nests and burrows.

If the bait is eaten and rats and mice are not caught, the trap probably needs fixing. Check for bent or rusted triggers, weak springs or loose wires.

Cats and dogs

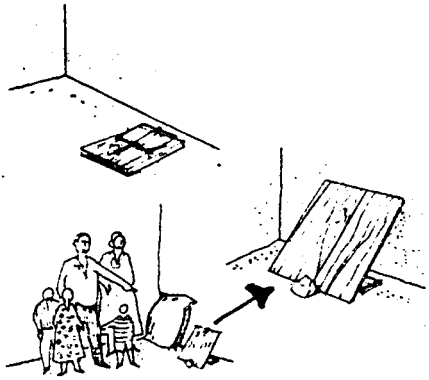
Cats and certain dogs will catch rodents or frighten them. Stimulate cats and dogs to be aound the stores.

7.2 Control of rats and mice by rodenticides

Rodenticides are poisons that kill rodents. Because these poisons are ment to kill warm-blooded animals, they are very poisonous to human beings, their children, their domestic animals and to wild animals.

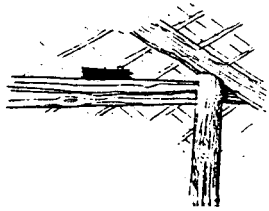
Warning
Because the rodenticides are used close to the stored product there is a good chance that the produce gets contaminated with the poison. Rodents can poison the food by walking over the poison and after that spreading it over the food. Therefore we strongly advise not to use rodenticides.
If there is no other way: Use them sparingly and carefully.

Another disadvantage of rodenticides is that they cost money and they are not always in stock.
Rodenticides should be used only when other means have failed and then only by someone who is familiar with their use and their dangers. Instructions for use should be included with the container: follow these! If there are no directions for use, do not use the poison!



Warn your children about the traps, so they won't hurt themselves!

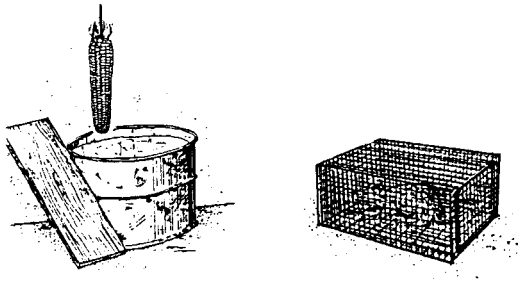
A: Putting traps close to the wall



Traps in high places

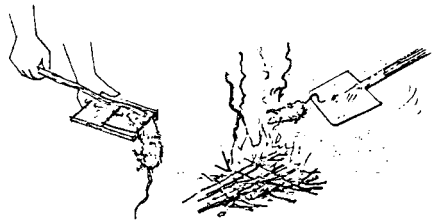
Hiding traps

B: Setting traps



C: Different type of traps

Wash the trap before using it again.



Use a stick to remove the dead rodent and burn it. Do not touch it barehanded.

D: Hygiene

Figure 15: Types of traps, placing and hygiene

7.3 Types of rodenticides

The rodenticides that are available will vary from area to area. They are sold under different trade names. Basically there are two kinds of poison used for killing rodents: **acute** poisons and **chronic** poisons.

Acute poisons

This is a group of poisons that cause a quick death if eaten by the rodents in small quantities. These are single dose poisons. Rodents need to eat only a mouthful of poison to die within half an hour. However acute poisons are **extremely poisonous** to man and domestic animals!

A practical problem is the bait-shyness induced by this type of poison: if the rat finds the taste of the poison suspicious, he will stop eating it and not swallow enough poison to die. The rat will recover and for a long time he will refrain from eating this type of bait or anything that tastes alike.
Rodents also learn very quickly; as soon as a member of the species is found dead from poison the others will avoid the poison.

TAKE CARE!
Acute poisons are extremely dangerous to man and domestic animals.
- They must be handled by an experienced person, who is aware of the precautions to be taken to avoid accidents.
- Normally they must be used outside, NEVER in stores containing foodstuffs.

The most common acute poisons are:
- **Arsenious oxide**:
  Approximately 40 milligrams is needed to kill a 200 gram brown rat.
- **Zinc phosphide**:
  Used in baits to which fats are added to increase its effect. Less than 10 milligrams is needed to kill a 200 gram brown rat.
- **Sodium monofluoroacetate**:
  This poison is not allowed in Europe. It is 20 times more toxic than Zinc phosphide. Its use is not recommended in hot countries.

- **Antu**:

should only be used against the brown rat.

Chronic poisons

The chronic poisons or slow poisons are used in lower dosages than the acute poisons. They are added to a food for the rat or mice to eat (bait). They must be eaten for a number of days before death occurs. These poisons cause rodents to bleed inside their bodies. The bleeding occurs from old wounds and thin tissues inside the body, and it will not stop.

The chronic poisons have no taste and no smell. The rodents do not know they are being poisoned. This is an advantage because they continue to eat the poisoned food. A disadvantage may be that it requires a lot of poison, a lot of bait and a long time to use chronic poisons well. Another disadvantage is the price. Chronic poisons are more expensive than acute poisons. On the other hand they are less dangerous to man (although still highly toxic) and more effective against rats.

The most common chronic poisons are:

- **Coumafen** (or **Warfarin**):
  This was for a long time the most popular anti-coagulant. Chlorophacinone is now preferred.
- **Chlorophacinone**:
  Acts in smaller doses than the other slow-acting poisons.
- **Bromadiolone**:
  Useful against species that are resistant to coumafen and chlorophacinone.
- **Difenacoum**:
  Effective against rats that are resistant to coumafen.
- **Diphacinone**:
  A bait which is already mixed with a certain rodenticide.

WARNING!
Chronic poisons are also **extremely dangerous** to man and domestic animals. Because the chronic posisons have to be available for the rodents for a longer period, the danger that children, cats or dog eat them is much bigger.

7.4 The application of rodenticides

Rodents will not eat a poison in its pure form. You should make the poison attractive to encourage the animal to eat. To do so the poison is mixed with a kind of food rodents like. This food is called the **bait**.

Choosing a bait

If possible the bait should be more attractive than the usual food (stored product), to encourage the rodent to eat it in stead of the normal food. It is very difficult to achieve this in a store where an unlimited amount of cereal or pulses is available. In this case the poison may be added to water, because rats living in areas with dry products in stores need water. Other sources of water should be removed as much as possible.

The attractiveness of the bait may be increased by adding tasty substances to it, such as vegetable oils, peanut butter, vaseline or paraffin (50 ml /kg of bait), sugar (50 to 100 g/kg) or salt (4 g/kg).

Preparing a bait

Bait, poison and other substances must be carefully mixed with the grain or flour. It is very important to use the right amount of poison to be mixed with the bait. Instructions about the amount of poison per quantity of bait should be stated on the label on the package or container. Remember that more poison in the bait does not improve it. It can even reduce the effect by making the bait less attractive.

A bait can be prepared in several ways:

- **Dry baits with chronic poison** are prepared by just mixing grain or flour with a chronic poison.
- **Oily baits with chronic poison** are prepared in a similar way as the dry baits. After preparing the dry bait, oil is added and mixed carefully through the mixture. Oily baits are used in wet places or in places where the bait will be left for some time. The oil will preserve the bait.

- **Damp baits** are prepared by soaking cereals or bread in water for some time. Just before use the extra water is drained off. The correct amount of poison (see user instructions!) is added and mixed with the bait. Rodents like damp baits, but these baits dry out quickly. For this reason damp baits are usually used with acute poisons.
- **Liquid baits** are simply poisons dissolved in water. They may be acute or chronic types of poison. These baits are useful in dry situations where rodents take them as drinking water.
  Liquid baits however loose their power in two or three days under warm conditions.

All four types of bait will become more attractive when sugar, molasses or some sweet food is added.

When preparing baits, where protective clothing (gloves, mask and overall or a separate set of clothes) and do not let these lay around afterwards. Don' t touchyour face while working with poisons. Wash your hands. Don't leave empty bottles laying around. Burn them!

Baiting technique

To achieve maximum success in rodent control it is necessary to apply the following rules:

- Baits should only be put in places where signs of rodents are found.
- Baits must be placed in runways, near holes, burrows and nests but preferably in places which are not exposed.
- Baits should **never** be put straight on the bare ground. Put the bait in small containers like empty shallow tins, jar lids and cover them with pieces of bamboo, pipes, self-constructed bait boxes, etc. These measures help to hide the bait from other animals and to prevent the bait from getting wet.

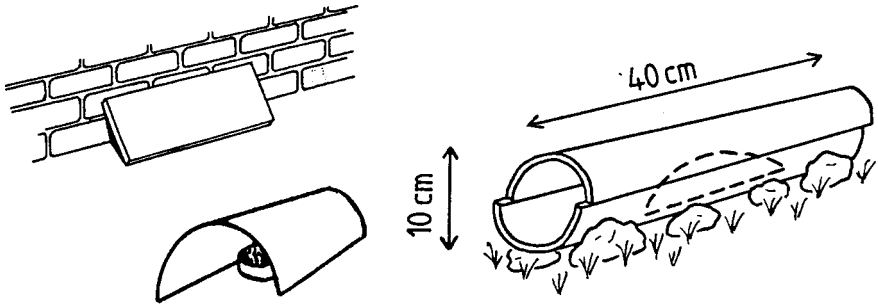


Figure 16: Examples of covering baits

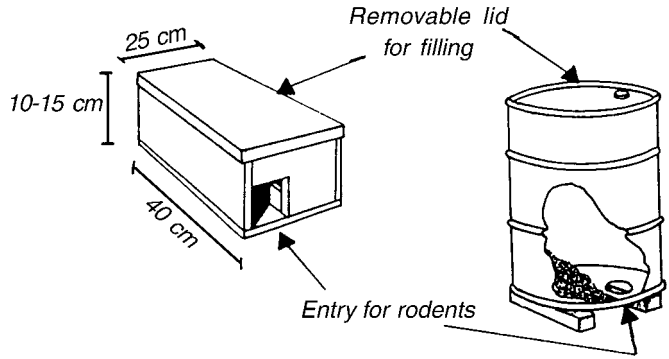
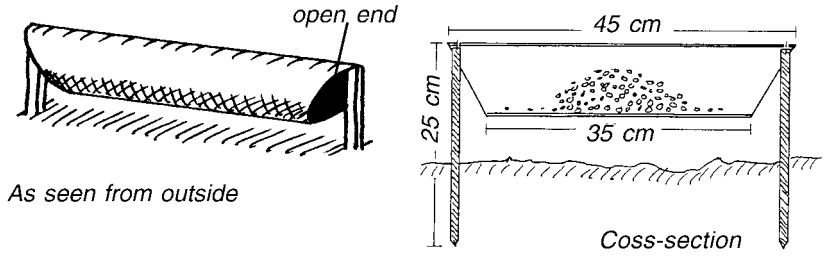


Figure 17: Simple bait containers

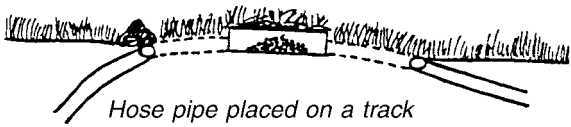
- There must be enough bait points. For the brown rat about 12 points for a area of some 3500 m^2 are recommended. The bait points should be spaced not more than 20 m apart and contain 400 g of bait.

  There should be more bait points if dealing with the black rat as it is more active than the brown rat. Some should be located on timbers or on top of the walls because of the climbing capacity of this rat. Only 100 g of bait should be placed at each baiting point.

  Mice are more difficult to catch by baiting points. The use of acute poisons against mice is recommended.



A fixed bait container made out of a piece of pipe 7-10 cm in diameter. Should be placed where there is dense vegetation on rodent tracks



Baiting containers made out of a piece of hose pipe.

Figure 18: Examples of fixed baiting containers

- Check the bait points every second day to make sure there is enough bait.
  - Note the bait points visited by the rodents and put some fresh food down where necessary.
  - Remove mouldy or insect-infested baits and replace them with new ones.
  - Smooth the bait so that next time you check you will be able to see signs of feeding. In case of brown rats, the bait may not be touched during the first week.

- If the bait is no longer eaten then pick up the container and burn the contents. Dead rodents must also be burnt. If there are still rodents move the bait point to another place.

For placing acute poisons the following method can be used as well:

- prepare 10 x 10 cm square papers, banana leaves, or other materials;
- put poisoned food in the middle at one end;
- roll up the paper and twist the ends;
- throw the paper packets into places where it is impossible to put traps, for example into holes and burrows, between walls, etc.

If violent rodenticides i.e. acute poisons are used, prebaiting should ideally be practised. This means that non-poisonous bait should be put in the appropriate points and renewed on the third day. On the fifth day, all the bait should be replaced by poisoned bait. On the eighth day this poisoned bait is removed once and for all. With the chronic poisons, there is no need to carry out preliminary baiting.

Appendix 1: Traditional storage methods

Table 3: Protection of stored cereals

Protective plant	Part	How to apply	Country of use
Andropogon spp.		The smell repels pests, thus protecting the grain.	Mali
Pepper wort	leaves seeds	Dried seeds or leaves are mixed with grains.	Nepal
Black pepper	fruit	0.5 % Black pepper on wheat gives 100 % mortality of adult Rice weevils.	
Cinnamon	bark	Raw bark attracts Rice weevils. If a few pieces are added to a sack of polished rice, the insects collect at the pieces and can then be removed and killed.	
Clematis vitalbla		Keeps grain in sacks insect free.	France
Cocoyam		Powdered cocoyam gives some protection against Rud-rest flour beetle due to the presence of calcium oxylate.	
Bastard feverfew (Parthenium hysterophorus)		Used to protect rice and sorghum.	India
Bullock's heart (Anona reticulata)	leaf seed	Used to mix with and cover sorghum, millet and cowpeas. 0.5 - 2 % w/w seedpowder gives complete protection against Cowpea bruchids for 3 months through its repellent effect.	
Eucalyptus spp.	bark	Raw bark attracts Rice weevils if a few pieces are added to a sacks of polished rice. The insects can then be removed and killed. See also Cinnamon and Persian lilac.	
Fenugreek		Mix with grain in sacks.	India
Hyptis spicigera	leaves	Dried Hyptis leaf powder protects stored millet against termites.	
Inula graveolens		Mix with grains to protect against weevils.	Greece
Costus	roots	The roots are used to protect fabrics. In trials 2 % powdered root was ineffective against the Khapra beetle in wheat.	Kashmir

Protective plant	Part	How to apply	Country of use
Lime	leaf	Used to protect rice.	Sri Lanka
Margosa	leaf	Used to protect rice.	Sri Lanka
Marjoram		Mixed with grain to protect against weevils.	Greece
Mexican marigold	plant	Whole plant protects stored maize through its overpowering smell.	Kenya
Mundulea sericea	leaf	Fresh and dried leaves used to protect sorghum, paddy and pulses.	India
	root	2.5 % root extract spray gave 86 %knockdown against Saw-toothed grain beetle in trials.	India
Neem	leaf	5-7 cm thick layer of leaves is spread over a large quantity of grain.	India
	fruit	Fruit is smeared over the walls of the storage space.	India
	seed	Powder made from neem seeds is widely used with stored products. The powder mixed with wheat at a rate of 10-20 g per kg of wheat (1-2%) protects the wheat against Rice weevils, Lesser grain borers and Khapra beetles for almost one year.	India Punjab Bangladesh
	leaf seed	Impregnation of bags with neem oil at a rate of 1 g/m2, or powder at 300 g/m2 reduces the population of adults of the Lesser grain borer.	
Persian lilac	bark	Raw bark attracts Rice weevils if a few pieces are added to a sack of polished rice. The insects can then be removed and killed.	
	fruit leaves	Against moths and to protect grain and cloth. 5-7 cm layers of leaves are spread through heaps of grain. Mud containing crushed leaves is used to plaster stores. Crushed fruit or leaf powder (4 %) protected wheat against Angoumois grain moth in trials.	Pakistan
	seeds, leaves	Powder from dried seeds (10-20 g per kg of wheat, 1-2%) or dried leaves (40-80 g per kg of wheat, 4-8%) gave good protection against Angoumois grain moth for at least 4 months.	
Red pepper	fruit	Peppers mixed with ash and dung are used with grain.	Nigeria
	fruit	Red peppers are used to protect rice.	Gambia
	fruit	Ground rice is stored with 2 chillies per 80 kg rice.	Malaysia
	fruit	Red peppers placed in sacks of maize or rice give protection for 6-12 months.	Philippines

Protective plant	Part	How to apply	Country of use
Red pepper	fruit	Fires in which pulverised chillis are burnt should be lit monthly underneath the store. Very effective. Disadvantage: the smoke is very sharp and uncomfortable for eyes and respiratory system.	
	seed	Burnt seeds were used for more than 400 years by the Aztecs to protect maize.	Mexico
Ryania (Ryana speciosa)		400 g/ton protects large quantities of shelled maize and wheat for 2 years. Also good protection for groundnuts.	
Sour clove (Melilotus indica)		Layers of 5-8 cm are mixed with grain.	India
Spearmint	leaves	Powdered leaves mixed with wheat at 0.5 % gave good control of Rice weevils. Mortality occurred between 24 and 96 hours after treatment.	
	leaves	10-20 g leaf powder mixed with 1 kg of wheat (1-2%) protects the wheat against Rice weevils.	
Sunn hemp	seeds	Spread seeds on the ground and put bags on top of the seeds. Continue layering sunn hemp seeds and bags of stored grain. Used for rice and maize.	
Sweet flag	rhizome	Used to protect wheat and rice.	Pakistan
	rhizome	Dried rhizomes are mixed with rice at a concentration of 1 % before it is stored.	India
	rhizome	Before grain is stored it should be well mixed with dried powdered sweet flag rhizome at the rate of 50 kg grain : 1 kg sweet flag powder (2%). For rice a rate of 100 kg rice : 1 kg sweet flag powder is recommended.	
Turmeric	rhizome	2 % rhizome powder is mixed with wheat and rice.	Pakistan
Wild tobacco	leaves	Dried, chopped leaves are mixed at 2 % with rice and wheat.	
Plant extracts			
Bitter wood		Walls are treated with solution to prevent infestation by the Tropical warehouse moth.	
Jewelvine (Derris eliptica)	roots	100 % kill of Rice weevils on rice was obtained with 3 % rotenone (active compound in Derris roots) on kaolin in 6 days and with 1 % rotenone on kaolin in 15 days. The Derris extract is poisonous!	

Protective plant	Part	How to apply	Country of use
Jewelvine (Derris eliptica)	roots	0.25 % root extract spray gave 96% knockdown of the Saw toothed grain beetle in trials.	
Moneywort		Oil extract destroys grain insects.	
Sweet flag	rhizome	Works well against the Cowpea bruchid, the Rice weevil, the Khapra beetle and some other storage pests when these species were placed with pulses and cereals treated with the oil or fragments of crushed rhizome.	
Minerals			
Activated coal		Very effective against weevils.	
Fine sand		Maize is mixed and covered with dry, sieved fine sand and kept in oil drums or large covered wooden boxes. A 10 litre bucket of sand mixed with 100 kg of stored grain or peas gives some protection against storage pests; the more sand used the better. The top is covered by a layer of sand.	Lesser Antilles
Heat-activated claydust		Very effective against weevils.	
Kaolin/lime		Mixed with cereals at 1 % to protect against weevils.	Greece
Lime		Layered with maize cobs with husks on in wooden boxes. Used by Aztecs mixed with maize. Lime is commonly added to stored maize.	Philippine Mexico Honduras
Quartz		Hard abrasive mineral dust such as quartz is very effective against weevils.	
Ashes			
Acacia		Used to protect sorghum, paddy and pulses	India
Casuarina spp.		Used to protect sorghum, paddy and pulses.	India
Cow dung ash		Mixed with maize and other cereals.	Botswana
Mahogany		Thick layers are admixed with millet in earthenware pots.	Ghana
Mango wood		Used to protect sorghum, paddy and pulses.	India
Rice husk ash		Used for rice storage. Mixed with paddy and stored in bins. Very effective against grain weevils.	Japan India
Tamarind		Used to protect sorghum, paddy and pulses.	India

Protective plant	Part	How to apply	Country of use
Wood		Admixed with grain. Sufficient ash is used to cover up to 2 tonnes of wheat, maize and cowpeas. Mixed with maize and millet in small containers sealed with mud. Admixed with millet, sorghum, sesame and maize or dusted on granary walls. Admixed with millet and dusted on walls. Admixed with grain on the threshing floor . Admixed with maize and stored in reed bins. Spread over husked maize or mixed with bagged beans and cowpeas.	N-Nigeria Egypt Nigeria Burkina Faso Mali Botswana Swaziland Mexico
Cow dung ash		Mixed with crops and with cereals kept for seed.	Punjab
Grass		Burnt grass is mixed with millet seed for protection against weevils.	Ghana
Husks, shells, chaff and other plant waste			
Chaff		Compressed leaves of chaff can protect cereals stored in cribs for 2-3 years.	
Fried rice		Fried rice spread on pulses will help to keep away insects.	
Paddy husk		Stored paddy is covered with a 25 cm thick layer of paddy husk to act as a barrier to moisture and pests.	Iran
Sorghum husk		Additional sorghum husk protects sorghum to a limited extent.	
Smoke			
Any		Bulrush millet and sorghum is kept in smoke in tightly woven baskets.	Malawi
Camphor		Burning camphor is found to be effective.	India
Oils			
cashew nut		Toxic to the Saw toothed grain beetle and the Foreign grain beetle.	
garlic		Some effect against adults and larvae of the Khapra beetle.	
Hardwood tar		7.5 % oil on inert dust was applied to wheat at a rate of 10 oz per 50 lb of seed. The wheat was protected for 8 weeks against the Confused flour beetle, the Lesser grain borer and the Grain weevil.	
Pongammia pinnata		Used as grain protection.	India

Table 4: Protection of stored pulses

Protective plant	Part	How to apply	Country of use
Black pepper	fruit	Pepper admixed with yellow-eyed beans at 1 % reduced damage by Common bean weevil by over 90 % compared with the control.	
Cactus spp.	plant	Cactus powder mixed through pulses offers protection.	Burkina Faso
Cassia nigricans	leaves	The whole leaves of this plant are layered between the beans which are stored in their pods. The leaves protect the beans against the bean weevil.	Burkina Faso
	leaves	Beans treated with a ratio of 3 g per kg (0.3 %) of dried leaf powder are much less prone to damage from newly hatched larvae.	
Bastard feverfew		Used to protect pulses, as well as rice and sorghum.	India
Hyptus spicigera	leaves	The leaves of this plant are laid whole between the beans which are stored in their pods. The leaves protect the beans against bean weevil infestation.	Burkina Faso
	leaves	Beans treated with a ratio of 3 g per kg (0.3 %) of dried leaf powder are less prone to damage from newl larvae.	
Five-leaved chaste tree	leaves	Leaves are used to protect sorghum and pulses (in trials this method seems to be not very effective).	India
millet	leaf	A layer of leaves is laid over the pulses.	India
Mundulea sericea	leaf	Fresh and dried leaves used to protect sorghum, paddy and pulses.	India
	root	2.5 % root extract spray gave 86 % knockdown against Saw toothed grain beetle in trials.	
Pea	pulse	In trials mixing equal weights of yellow split peas and wheat reduced the activity of the Rice weevil. Other pulses did not have the same results.	
Ragi millet	leaf	A layer of leaves is laid over the pulses.	India
Red pepper	fruit	Crushed, dried fruits are mixed with pulses stored in sealed containers.	Gambia
	fruit	Beans mixed with dry finely milled earth and chillies are protected for several months.	Benin

Protective plant	Part	How to apply	Country of use
Red pepper	fruit	Fires in which pulverised chillies are burnt should be lit monthly underneath the store. Very effective. Disadvantage: the smoke is very sharp and irritating for eyes and respiratory system.	Philippines
Ryania		Gave excellent protection of groundnuts and maize (insecticidal effect). 400 g/tonne protected large bulks of shelled maize and wheat for 2 years.	
Spearmint	leaves	Powder of shade-dried spearmint leaves protects chick peas against cowpea beetles. 5 g powder mixed with 1 kg of peas is sufficient to kill about 90 % of the beetles within 48 hours.	
Thorn apple		In trials treatment with thorn apple reduced damage in groundnuts held in clay pots for 45 days.	
Tobacco	leaves	Leaves or snuff are mixed with beans for storage protection.	Zambia
Bullock's heart	leaf seed	Mix and cover cowpeas with the leaf 0.5-2 % w/w seedpowder gave complete protection against cowpea bruchid for 3 months through repellent effect (trial).	
Lalang	plant	Cowpeas are covered with the grass and placed in a barrel above a smoking fire. This provides up to 5 months protection.	Nigeria
Hyptis spicigera	flower	Protection of cowpea through the pungent smelling inflorescence. In trials groundnuts mixed with dry chopped leaves were also protected against Groundnut borers.	Nigeria
Red pepper	fruit	Powdered red peppers are sprinkled over shelled cowpeas.	Nigeria
Wild clove (Pimenta acris)		Mixed with pigeon peas in the pod, stored in sacks.	Lesser Antilles
Neem	Leaf	The leaves are used to protect cocoa beans against moths.	Ghana
Hoary brasil		Used in general to protect stored produce.	Nigeria
Lantana rugosa		Used in general to protect stored produce.	Nigeria
Arrowroot (Tacca leontopetaloides)		Used in general to protect stored produce.	Nigeria
Illipe butter tree (Madhuca latifolia)	80 % kill of Cowpea bruchid.		

Protective plant	Part	How to apply	Country of use
Malabar nut tree	leaves	1% dried powdered leaves give good protection against Angoumois grain moth and Lesser grain borer.	
Mundulea sericea	bark	Stem bark powder is effective against bruchids (no more details given, trials).	
Shea butter tree		Used in general to protect stored produce.	Nigeria
Smooth loofah		Used in general to protect stored produce.	Nigeria
Soap berry	berries	Application of 3 berries per bushel in powder or liquid form repells weevils and other insects.	
Worm wood		Used traditionally against pests.	Pakistan
Plant extracts			
Neem	seeds	2-3 ml of neem oil (see section 5.2 for the recipe of the oil) admixtured with 1 kg of beans protects the beans in store from bruchid infestation. It is important to ensure that the oil is well mixed so that each bean is completely coated. Protection lasts about six months.	
Sweet flag	rhizome rhizome	Pulses and cereals treated with the oil or fragments of crushed rhizome are protected against the Cowpea bruchid, the Rice weevil, the Khapra beetle. For the recipe of the oil, see section 5.2. Essential oils are obtained from the rhizomes by steam destillation. Dried chicken peas dressed with a 4% oil-water emulsion (4 ml of oil mixed with 100 ml of water) will be protected against pests for at least 4 months. The mixture of essential oil and water should be vigorously shaken before use. The protection appears to last longer when the treated seed is not exposed to sunlight.	
Minerals			
Sand, earth		Admixture with groundnuts. Mixed with cowpeas which are then sealed in calabashes. Used for storage of peppers, tobacco, beans and sesame seeds.	Senegal Zaire Indonesia
Fine sand		10 litres (1 bucket) of sand mixed with 100 kg of stored grain or peas gives some protection against storage pests; but the more sand used, the better. The top is covered by a layer of sand.	

Protective plant	Part	How to apply	Country of use
Termite soil		Beans are coated with a paste of termite mound soil and then stored in small containers.	Uganda
slaked lime & wood ash		0.3% of these mineral dusts (3 parts of dust mixed with 1000 parts of beans) protects cowpea against the Cowpea beetle.	Jamaica
Ashes			
Acacia		Used to protect sorghum, paddy and pulses.	India
Casuarina spp.		Used to protect sorghum, paddy and pulses.	India
Mango tree		Used to protect sorghum, paddy and pulses.	India
Tamarind		Used to protect sorghum, paddy and pulses.	India
Wood		Admixed with beans, cowpeas, unshelled groundnuts, lentils, chick peas and other types of pulses.	several countries
Husks, shells, chaff, and other plant waste			
chaff		Finger millet chaff is used to protect beans.	Zambia
sawdust		A 2 cm layer of sawdust will protect pulses against bruchids and prevent their emergence.	
Oils			
Animal fat		1 ml of lard per 1kg of beans gives 6 months protection against Common bean weevil.	
Castor		5 ml of oil per kg of cowpeas gives effective protection against the Cowpea bruchid for 6 months. No effect on taste, cooking time or germination percentage noticed. Treatment of green gram with 0.3 % oil prevents multiplication of the Cowpea bruchid.	
Citrus		Fruit peel extracts in a concentration of 0.25-1% w/w protects black-eyed peas against Cowpea bruchid.	

Protective plant	Part	How to apply	Country of use
Coconut		5 ml of oil mixed with 200 g of cowpeas protects cowpeas against infestation. Treatment of green gram with 0.5 % oil prevents multiplication of Cowpea bruchid. 5 ml of oil per kg of cowpeas gives effective protection against Cowpea bruchid for 6 months. No effect on taste, cooking time or germination percentage noticed.	
Garlic		Some effect against adults and larvae of the Khapra beetle in ground nuts	
Gingili		Treatment of green gram with 0.3 % oil prevents multiplication of the Cowpea bruchid.	
Groundnut		5 ml of oil per kg of cowpeas gives effective protection against the Cowpea bruchid for 6 months. No effect on taste, cooking time or germination percentage noticed. Groundnut oil is more effective than castor, palm kernel, and coconut oil. 5 ml of oil mixed with 200 g of cowpeas protects cowpeas against infestation. Treatment of green gram with 0.5 % oil prevents multiplication of the Cowpea bruchid.	
maize		5 ml of oil is effective to prevent Zabrotes subfasciatus infestation in beans.	
mustard		Treatment of green gram with 0.3 % oil prevents multiplication of the Cowpea bruchid.	
palm		5 ml of oil per kg of pigeon peas, and some other beans protects these beans for 3 months against infestation of several storage pests. 10 ml per kg gives 10 months protection. No effect against the Maize weevil and the Rust-red flour beetle.	

Protective plant	Part	How to apply	Country of use
palm kernel		1 ml of oil is completely effective in preventing Zabrotes subfasciatus infestation in beans. 5 ml of oil mixed with 200 g of cowpeas protects cowpeas against infestation. 5 ml of oil per kg of cowpeas gives effective protection against the Cowpea bruchid for 6 months. No effect on taste, cooking time or germination percentage found.	
sour orange		The oil consisting of 98 % limonene gives 100 % mortality of Cowpea weevils in 24 hours in airtight plastic or metal containers.	
soyabean		5 ml of oil is effective to prevent Zabrotes subfasciatus infestation in beans.	

Table 5: Common storage pests
(Source: Oudejan, J.H., ESCAP/UN, 1991)

Common name	Scientific name	Produce
Beetles and weevils		
Larger grain borer	Prostephanus truncatus (L)	Maize, dried cassava
Lesser grain borer	Rhizopertha dominica (F.)	Cereal grains, pulses, root crops
Dried bean beetle	Acanthoscelides obtectus (Say)	Pulses pre- and post-harvest
Adzuki bean beetle	Callosobruchus chinensis (L.)	Pulses (especially peas and grams)
Cowpea weevil, pulse weevil	Callosobruchus maculatus (F.)	Pulses (especially peas and grams)
Groundnut beetle	Caryedon seratus	Unshelled groundnuts
Bean seed beetle	Zabrotus subfasciatus (Boh.)	Pulses (especially beans)
Copra beetle	Necrobia rufipes (De Geer)	Copra, oilcake, oilseeds, cocoa beans
Rust-red grain beetle	Cryptolestes ferrugineus (Steph.)	Cereal grains
Flat grain beetle	Cryptolestes pusillus (Schoen.)	Cereal grains
Granary or grain weevil	Sitophilus granarius (L.)	Cereal grains
Rice weevil	Sitophilus oryzae (L.)	Cereal grains
Maize weevil	Sitophilus zeamais (Motsch)	Cereal grains
Khapra beetle	Trogoderma granarium (Everts)	Cereal grains, groundnuts
Corn sap beetle	Carpophilus dimidiatus (L.)	Cereal products, dried fruits
Spider beetle	Ptinus tectus (Boieldieu)	Grain products
Foreign grain beetle	Ahasverus advena (Waltlus)	Cereal grains and products, copra, herbs
Saw-toothed grain beetle	Oryzaephilus surinamensis (L.)	Cereal grains and products
Merchant grain beetle	Oryzaephilus mercator (Fauvel)	Cereal grains, dried fruits, oilseeds
Black fungus beetle	Alphitobius diaperinus (Panzer)	Cereal grains and products
Long-headed flour beetle	Latheticus oryzae (Waterhouse)	Cereal grains and products
Depressed flour beetle	Palorus subdepressus (Woll)	Cereal grains and products, pulses
Red flour beetle	Tribolium castaneum (Herbst)	Cereal grains and products, pulses

Common name	Scientific name	Produce
Confused flour beetle	Tribolium confusum (Duval)	Cereal grains and products, pulses
Cadelle beetle	Tenebroides mauritanicus (L.)	Cereal grains, cocoa, oil-seeds
Dried fruit beetle	Carpophilus hemipterus (L.)	Dried fruits
Drug-store beetle	Stegobium paniceum (L.)	Grain products, drugs, dried plants, herbs
Coffee-bean weevil	Araecerus fasciculatus (De Geer)	Coffee and cocoa, beans, spices, maize
Powder-post beetle	Dinoderrus minutus (F.)	Bamboo, cassava
Cigarette beetle	Lasioderma serricorne (F.)	Tobacco products, groundnuts, cocoa
Moths		
Angoumois grain moth	Sitotroga cerealella (Oliver)	Cereal grains
Rice moth	Corcyra cephalonica (Stainton)	Cereal grains and products, groundnuts, dried fruit, oil-seeds
Tropical warehouse moth	Ephestia cautella (Walker)	Cereal grains and products, dried fruits, groundnuts, beans
Mediterranean flour moth, mill moth	Ephestia kuehniella (Zeller)	Milled cereal products, particularly flour
Indian meal moth	Plodia interpunctella (Hubner)	Cereal grains, dried fruits, groundnuts
Potato moth	Phtorimaea Operculella	Stored potatoes
Flour or grain mite	Acarus siro (L.)	Cereal grains and other products
-	Liposcelis species	Cocoa, maize

Appendix 2: The Salt-test

A very simple method for testing the suitability of grain for storage is the salt-test. **Dry** common salt (non-ionized) is mixed with the grain sample in a glass jar and shaken. The equilibrium relative humidity of dry salt is 75 % at ambient temperature. The equilibrium moisture content of grain at 75 % relative humidity is about 15 %. This is about the moisture content which is regarded as 'safe' for grain storage. So, if the salt in the grain sample adheres to the walls of the glass, it has absorbed moisture from the air. This means that the relative humidity of the air is more than 75 % and so the moisture content of the grain must be higher than 15 %, unsuitable for storage. This salt-test in not precise, but it costs little and is simple to carry out.

Experienced people may be able to estimate the suitability of the grain for storage by sight, feel and hardness of the individual kernels. Also squeezing some kernels may help them to determine the moisture content approximately.

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