Grain Storage and Pest Management

The purpose of any grain storage facility is to prevent grain loss from weather, moisture, rodents, birds, insects, and microorganisms.

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1 Introduction

The purpose of any grain storage facility is to prevent grain loss from weather, moisture, rodents, birds, insects, and microorganisms. Rice storage facilities take many forms depending on the quantity of grain to be stored, the purpose of storage, and the location of the store. In general, it is recommended that rice for food purposes be stored in paddy form rather than milled rice as the husk provides some protection against insects and helps prevent quality deterioration. However, when rice can be stored as brown rice, 20% less storage capacity will be needed

The requirements for a good storage system include:

- Prevention of moisture re-entering the grain after drying
- Protection from insects, rodents and birds
- Ease of loading and unloading.
- Efficient use of space
- Ease of maintenance and management.

Rice grain is hygroscopic and in open storage systems the grain moisture content will eventually equilibrate with the surrounding air. High relative humidity and high temperatures contribute to high equilibrium or final moisture content. In many tropical countries, the equilibrium moisture content is above safe storage moisture levels.

2 Safe storage conditions for grain

Safe storage of rice for longer periods is possible if three conditions are met:

- Grain is maintained at moisture levels of 14% or less and seed is stored at 12% or less
- Grain is protected from insects, rodents and birds
- Grain is protected from re-wetting by rain or imbibing moisture from the surrounding air.

The longer the grain needs to be stored, the lower the required moisture content will need to be. Grain and seed stored at moisture contents above 14% may experience the growth of molds, rapid loss of viability and a reduction in eating quality. The following table shows the 'safe' moisture content required for different storage periods.

Storage period	Required moisture content for safe storage	Potential problems
Weeks to a few months	13-14	Molds, discoloration, respiration loss, re-wetting if stored at high humidity
8 to 12 months	12- 13 %	Insect damage
More than 1 year	9 % or less	Loss of viability

A rule of thumb for seed is that the life of the seed will be halved for every 1% increase in moisture content or a 5^{o}C increase in storage temperature.

3 Grain Storage systems

Grain storage systems can be classified as either bag or bulk.

3.1 Bag storage system.

In most parts of Asia grain is stored in 40-80kg bags made from either jute or woven plastic. Depending on the size of storage, these bags are normally formed into a stack.

Figure 1: Most of the rice in Southeast Asia is stored in bags in on farm and in the industry

When using bag storage consideration needs to be given to the following:

- Jute bags should not be stacked higher than 4m and plastic bags 3m. Plastic bags are more slippery and the stacks will be less stable
- Bags should be stacked under cover e.g. under a roof, in a shed or granary or under water proof tarpaulins
- A one meter gap should be left between and around stacks and 1.5 meters clearance between the top of the stack and the roof
- Bags should be stacked on pallets or on an above ground structure to avoid the possibility of absorbing moisture from the floor.
- Bags should **not** be stacked on a bed of rice husks or bags filled with rice husks, as these are difficult to keep free from insect infestation.
- Bags should be stacked so that fumigation can be undertaken easily. The dimensions of the stacks should be set to facilitate sealing with a single fumigation sheet.
- The efficiency of bag storage can be improved if a plastic liner bag is used inside the existing storage bag especially for seed and milled rice

Some farmers use bag storage in outside granaries, which have been constructed from timber or mud/cement or large woven bamboo or palm leaves.

3.2 Bulk storage

At farm level grain is often stored in bulk in small outside granaries or in woven baskets or containers made from wood, metal or concrete, which are located under or inside the house. These storages vary in capacity from 200-1000kg. Losses from insects, rodents, birds and moisture uptake are usually high in traditional bulk storage systems.

Figure 2: Bamboo basket (left) and wooden granary (center) for farm level storage. Inside the granaries storage often lead to high losses (right)

The large export mills and collection houses sometimes use metal or concrete silos. These silos range in size from 20 to 2,000 ton capacity. Silos have the advantage that they can be more easily sealed for fumigation and less grain is spilt or wasted. While bulk storage warehouses are not very common in Asia some can be found at the commercial sector e.g. in Thailand and Myanmar.

Figure 3: Steel silos are not commonly used in the tropics because of condensation problems with high moisture grains; few millers and traders have warehouses for bulk storage (right)

3.3 Hermetic Sealed storage

Sealed or hermetic storage systems are a very effective means of controlling grain moisture content and insect activity for grain stored in tropical regions. By placing an airtight barrier between the grain and the outside atmosphere the moisture content of the stored grain will remain the same as when the storage was sealed. The moisture content of the grain will then determine the relative humidity level inside the storage unit. Respiration by the grain and insects inside the storage, change the inter-granular atmosphere by consuming oxygen and expiring carbon dioxide. Depending on the number of insects, and type and size of the system, oxygen levels will be reduced from 21% to less than 10% within a short period of time. At oxygen levels below 10%, insects are curtailed and the viability of seed doubled i.e. from 6-12months

Figure 4: Hermetic storage systems made from locally available containers (left); the hermetic IRRI Super bag for 50kg (center); and a hermetic Cocoon™ with 5t capacity (right)

Sealed storage containers come in all shapes and sizes. They may range from a small plastic container, a sealed 200-liter drum to the more complex and costly sealed plastic commercial storage units. Recent technological advances in plastic manufacturing have led to the development of PVC liners that provide the required durability to climate, gas permeability and physical properties that enable airtight storage for extended periods of time.

For storage of small seed lots a variety of plastic bags or packages can be used. Different types of plastic have different resistance against transmission of water vapor. Glass jars, hard PVC or bags containing aluminum liners or a gas barrier will provide the best protection against moisture re-

entry. Polypropylene or polyethylene bags are the next best choice. Paper bags or flexible PVC bags for long-term storage of seed is not advisable.

4 Storage capacity

Different grains and components of grain have different weights. The following Table gives the approximate weight and volume for paddy rice and its milled components.

	Bulk (kg/m^3)	Bag (bags/ton)	Weight per bag
Paddy or rough rice	600-650	13-20	50-80 kg
White rice	850-900	20-25	40-50kg
Bran or meal	550-600	20	50kg
Husk	120-140		

To determine the storage capacity for different types of storages the following equations may help

- Square or rectangular bin:
  Volume = (length x width x height) x bulk density (kg/m^3)
- Tower silo with flat bottom:
  Volume = (22/7 x radius x height) x bulk density (kg/m^3)
- Tower silo with cone bottom:
  Total volume = Volume cylinder + volume of cone
  Total volume= (22/7 x radius x height) x bulk density (kg/m^3) + (1/3 (22/7 x height)) x bulk density (kg/m^3)
- Grain pile on a pad:
  Volume (length x width x 0.73 (grain coefficient))

In many storage devices allowances must be made for the angle of repose of grain (angle on the top of the grain stack). The angle of repose for rice, which is allowed to freely fall into a pile, is approximately 36 degrees.

5 Storage Hygiene

Good hygiene in the grain store or storage depot is important in maintaining grain and seed quality. Guidelines for hygiene in the grain store include:

- Keep storage areas clean. This means sweeping the floor, removing cobwebs and dust, and collecting and removing any grain spills.
- Clean storage rooms after they are emptied and this may include spraying walls, crevices and wooden pallets with an insecticide before using them again
- Placing rat-traps and barriers in drying and storage areas. Cats deter and help control rats and mice
- Inspect storage room regularly to keep it vermin proof.
- Inspect the stored seeds once a week for signs of insect infestation. When necessary and only under the direction of a trained pest control technician, the storage room or the seed stock may be sealed with tarpaulin and treated with a fumigants.

6 Major Storage Pests in Rice

Rice storage pests include insects, pathogens, rodents and birds. These pests cause losses through a combination of feeding, spoiling and contamination of both paddy and milled grain.

6.1 Insects

Environment

Each insect species has its own optimum temperature and moisture range conditions for development as well as a preferred feeding habit.

The optimum temperatures for most insect species range between 25 and 32°C. At temperatures below 14°C and above 42°C, the rate of development is reduced and most storage pests will die at temperatures below 5°C and above 45°C.

The optimum relative humidity for most species is around 70%, with the minimum 25 - 40% and the maximum 80 - 100%. Very few species are able to survive in extremely dry conditions.

Under good conditions, the duration of the development cycle from egg to adult is 18 - 25 days for beetles and 28 - 35 days for moths. In unfavorable conditions, this period may be extended to several months.

Insect activity and fertility are also affected by the change in light. Moths are most active at dawn and at dusk. Inspections to check and control flying insects are best made at these times. Artificial light can help to reduce the movement and fertility of moths. Most storage pests are able to penetrate a stack of bags more quickly and thoroughly than bulk grain because of the gaps between the bags. The size, the surface texture and nutrients in the grain also influence the ability of the pest to attack the grain

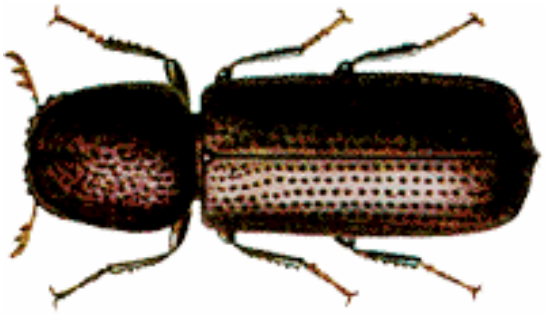
Insect Species

While many different species of insects are found in rice only a few are major pests. Insects in stored rice can be classified as either primary or secondary insects.

Primary Insects: These are insects whose larvae feed entirely within the kernels of the grain. These include the rice weevil, angoumois grain moth and lesser grain borer.

Rice Weevil (Sitophilos oryzae (Linnaeus)): Adults and larvae feed on a wide variety of grains and a female can deposit up to 150 eggs. A single egg is laid in each grain after boring a hole inside. The egg stays in the grain until it becomes an adult, and this completely damages the grain. The life cycle takes approximately 35 days under good conditions such as 28 °C and 70% relative humidity.

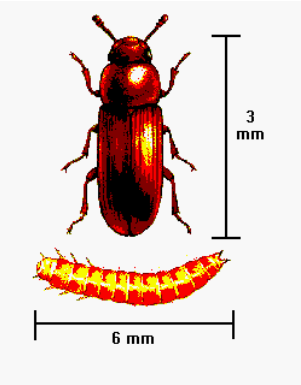
Angoumois Grain Moth (Sitatroga cerealella (Olivier)): Eggs are laid on or the near grain. The white larvae bore into the kernels of the grain and feed on the inside. When the larvae mature they eat their way to the outer portion of the grain, leaving only a thin layer of the outer seed coat intact. Pupation takes place just under the seed coat. When the adult emerges from the grain, it pushes aside the thin layer of seed coat leaving a small trap door covering its exit point from the kernel. They infest only the surface layer of bulk-stored grain, as adults are unable to penetrate deeply.



Lesser Grain Borer (Rhyzopertha dominica (Fabricus)): The eggs are laid in the grain mass and the larvae may enter the kernels and develop within or they may feed externally in the flour-like dust that accumulates from the feeding of the adults and other larvae. The optimum temperature for reproduction is 34°C and the optimal relative humidity is 60 -70% Females lay 300 – 500 eggs and the life cycle lasts 20 - 84 days

Secondary Insects are insects that feed from the outside of the grain even though they may chew through the outer coat and devour the inside. Two of the more prevalent secondary insects are the Saw-toothed Grain Beetle and the Rust-red flour beetle

Saw-toothed Grain Beetle (Oryzaephilus surinamensis (Linnaeus)): Eggs are usually laid, either singly or in small masses in a crevice in the grain but in products such as flour they are laid freely.



Rust-red flour beetle (Tribolium castaneum): The red flour beetles primarily attacks milled grain products. Both adults and larvae feed only on the grain dust and broken kernels and do not attack the undamaged whole kernels. Infestation leads to persistent and disagreeable odors of the rice. The optimum temperature for reproduction is 35°C and a relative humidity of 75%. The red flour beetle can lay up to 500 eggs and has a life cycle of 20 days under optimum conditions

Management of storage insects

The management of stored grain pests should be done in a sequential and integrated manner. An effective pest control system involves

- Harvesting, drying and storage of clean dry grain
- Disinfecting the storage system and
- Controlling or preventing pest infestation during the storage period.

Harvesting, drying and storage

Grain must be dried to at least 14% moisture (wet basis) and seed grain should be dried to12% moisture before storage. Grain needs to be harvested and dried so that it will not cause cracking of the grain, as cracked grains are easier for insects to infest.

This requires:

- Harvesting and threshing at the correct stage of maturity (20-25% moisture content)
- Drying the grain at a rate and temperature that will not damage the grain. The first stage of drying from 25% moisture to 18% can be done at high temperatures e.g. above 50-60^{o}C. After this the grain needs tempering or cooling for at least 4 hours. Drying from 18% to 14% moisture should be much slower and the temperature should not exceed 42^{o}C.
- When sun drying, the grain should be spread in thin layers, 2-4cm. Turn or stir the grains for at least once an hour; better if every 30 minutes. When sun-drying seed, the grain should be turned more often and not exposed to temperatures above 42^{o}C. If high temperatures occur the seed should be dried in the shade.

New grain should not be stored near older grain unless all insects have been eliminated from the older grain. It is preferable to store grain as paddy or rough rice as this is less susceptible to insect

attack than milled rice. Parboiled rice is also less susceptible to damage than raw rice.

Grain stores must have a damp proof floor and have waterproof walls and roof. It is preferable to be able to seal the storage so fumigation is possible should the need arise. Sealing the storage also helps exclude rodents and birds. Where grain is to be stored in bags, the bags should be stacked on pallets at least 50cm away from the walls. Hermetic storage systems have proved to be an effective means of storing grain. By having a sealed atmosphere the insects utilize the O_2, expire CO_2 and eventually die through suffocation and dehydration. This will occur within 5-10 days depending on the level of insect infestation. Other benefits of a hermetic system are that the moisture content of the grain and storage environment remains constant, and the sealed system reduces the chance of damage by rodents and bird.

Disinfesting the storage system

Disinfestations require a systematic and thorough cleaning of all sources of infestation before storage. Old grain residues in the storehouses, grain bins, harvesting and threshing equipment should be treated, removed or destroyed.

Storage containers, structures and equipment can be treated with:

- Malathion (50EC) at 5ml/20l of water @20ml/m^2
- Fenitrothion (50EC) at 5ml/l water @20ml/m^2
- Deltamethrin (2.5% WP) at 1.5g/l water @20ml/m^2

If thorough cleaning of containers is not possible, the containers may need to be sealed and fumigated with phosphine. All second hand bags should be examined and where necessary treated with either a fumigant, insecticide or dipped in boiling water. Solutions of Malathion (50EC) and Fenitrothion (50EC) at 5ml/20l of water and Deltamethrin (2.5% WP) at 1.5g/l water @20ml/m2 can be used for dipping the bags.

Controlling infestations within the grain

Consumers are increasingly demanding grain that is free from live insects and free from chemical residues caused by controlling pests. While many chemical sprays are registered for rice, some markets will not accept grain treated with these registered chemicals. Farmers should always check with buyers to ensure that the pest control methods intended for use will be acceptable.

The first step in controlling any infestation is to determine the level of infestation and then select an appropriate method for control. All storage should be checked, preferably every fortnight, and at least monthly. Random samples need to taken from all grain and tested for infestation. If there are more than 4 insects per kg some form of treatment is required. A simple rule of thumb for the number of bags to be sampled is to use the square root of the lot size. For example if there are 100 bags in the lot, samples should be taken from 10 bags.

Grain treatments

It is not recommended to use synthetic insecticides with rice that is for consumption. Only chemicals registered for direct application to rice grain should be used and these should be applied according to the label.

Malathion is a widely used chemical and is toxic to insects if it comes into direct contact with the pest. Malathion is considered one of the safest organophosphate insecticides as it is not highly toxic to humans or pets, and breaks down fast under tropical conditions. Malathion will not penetrate piles of grain. Although it is not usually recommended, it is still legal to treat grain with Malathion at 8 parts per million concentrations. As a grain treatment Malathion is applied at the time grain is stored. Treated grain should not be sold for at least 7 days nor eaten within 60 days of treatment. Safety precautions must be observed when applying Malathion or any other chemical.

Fumigation

Fumigants are effective against storage pests because as gases they can reach the pests in the

most remote hiding place. The range of safe fumigant chemicals that can be used is now restricted to phosphine and carbon dioxide.

Phosphine fumigation

Phosphine fumigation is undertaken using tablets and pellets. These tablets and pellets release phosphine gas when they come into contact with humid air. Phosphine is toxic to all insects. When insects are exposed to fumigation in a sealed environment all stages of development from the eggs, larvae, pupae to adults are killed.

Phosphine does not impair the grain nor leave residues that could be hazardous to the consumer when correctly applied and the grain aerated. Care must be taken when using phosphine as a gas as it is very toxic to humans. Fumigation must take place in an enclosure that can be tightly sealed. Once the exposure time is ended, the grain must be aerated and the bin checked for residual phosphine gas before entry.

Table 1: Minimum Exposure times at 60% Relative Humidity

Temperature (^{o}C)	Tablets (days)	Pellets (days)
Under 5	No fumigation	No fumigation
5-10	10	8
11-15	5	4
16-25	4	3
Over 25	3	3

Example: at 25^{o}C, the minimum exposure time for tablets and/or pellets is 3 days

Carbon dioxide fumigation

Insects need oxygen for respiration. With carbon dioxide fumigation, much of the oxygen in the storage bin is replaced by carbon dioxide that suffocates, dehydrates and also produces toxic chemicals in the blood of the insects. To be effective, elevated carbon dioxide levels must be maintained until all insects die. The required exposure time depends on the percentage of carbon dioxide and the temperature of the grain. The cost of CO_2 fumigation is high.

Table 2: Guidelines for Carbon Dioxide Application

Grain Temperature (^{o}C)	Minimum CO_2 Levels (%)	Days for control
25-30	80	8.5
25-30	60	11
25-30	40	17
25-30	20	Weeks to months

Physical conditions

Temperature

The ideal temperature for stored product insect growth is 25-30^{o}C. The lower the grain temperature the slower the insect populations increase. Aerating the grain immediately after harvest so the grain is cooled will significantly reduce insect infestation. At 15^{o}C the insects stop laying eggs and development stops. At lower temperatures insects will die.

High temperatures will also kill all stages of insects (eggs, pupae, larvae and adult) if exposed for a sufficient period of time. The most realistic use of high temperature is at drying or in some instances when the grain is being removed from storage for sale. Generally insects need to be exposed to temperatures of 50-55^{o}C for at least 15 minutes.

Impact

Certain insects are vulnerable to the physical impact caused by moving grain. Pneumatic conveyers subject the grain kernels to large forces and operate at high pressure. As insects go through the

pneumatic conveyer they are killed. Like high temperature this method may be useful when the grain is being moved for sale.

Diatomaceous earth

Control of some insects (e.g. rusty grain beetle) can be achieved by using a non-toxic dust made from prehistoric diatoms. When the insect comes in contact with this dust, the waxy covering on the exoskeleton is absorbed, leaving them prone to dehydration and death. The product is applied as the grain is loaded into the bin and is most effective when applied to dry grain at harvest. Control can take up to 5-6 weeks.

6.2 Fungi in stored rice

Contamination of seed and grain with fungal organisms may result in poor germination, seedling vigor or grain quality. Storage fungi usually invade grain or seed during storage and are generally not present in large quantities before harvest in the field. The most common storage fungi are species of Aspergillus and Penicillium. These fungi are widely distributed and almost always present. Contamination occurs through small quantities of spores contaminating the grain as it is going into storage from the harvest, in handling and storage equipment or from spores already in the storage structures. Under high temperatures and moisture this small amount of inoculum can increase rapidly. The development of fungi is influenced by the:

- Moisture content of the stored grain
- Temperature
- Condition of the grain going into storage
- Length of time the is grain stored and
- Amount of insect and mite activity in the grain.

Fungi cause two distinct problems in storage grains. These are grain spoilage from fungal growth or molds and the production of poisonous mycotoxins. Grain spoilage causes poor germination, loss of weight, loss of nutritive value, poor milling quality and deterioration in flavor and color of the rice. While the losses from spoilage may be of greater economic significance, they are less dangerous than the presence of mycotoxins. Mycotoxins are poisonous chemical compounds produced by certain fungal species that infect crops. While these fungi are not common in rice they have been isolated from rice.

Management Options

Safe Storage Conditions

Grain damage by fungi will be reduced when grain and seed is:

1. Stored at moisture contents below 13-14%. It is important to be aware that there is variation in moisture content through a grain mass and fungi will grow where moisture is suitable and not according to the average moisture content of the grain stack
2. Stored at temperatures below 20^{o}C and above 40o^{o}C.
3. Not cracked and broken kernels or contain large amount of foreign material - broken or cracked kernels are more likely to be contaminated going into storage and more likely to be invaded once they are in storage than whole kernels.
4. Free from fungi coming into store. Grains moderately invaded by storage fungi develop damage at lower moisture content, at a lower temperature and in a shorter time period than grain free or almost free of storage fungi.
5. Stored for a shorter period. Grain that is to be stored for only a few weeks before processing can be stored safely with a higher moisture content and more extensive invasion by storage fungi and can be kept at a higher temperature than grain that is to be

stored for months or years.

6. Free from insect and mites. Insects and mites can carry fungal spores on their bodies thus introducing storage fungi into the grain mass. Insect activity in a grain mass leads to an increase in both the temperature and moisture content of the grain surrounding the insect infestation. In these 'hot spots' conditions may be favorable for mold growth.

Grain treatment

Infected seeds can be treated by either physical or chemical treatments, or a combination of both methods. Seed borne bacteria can be treated by dry heat at 65^{o}C for 6 days or dipping in hot water treatment at 52-55^{o}C. Seeds can also be treatment with fungicides such as Dithane M-45 and Benlate at the rate of 3 grams kg^{-}1.

The most effective method of treating mycotoxin problems is avoidance. This is possible by drying the grain to a safe moisture content before storage, reducing physical damage to the grain during harvesting and storage and ensuring clean, dry insect-proof storage conditions.

Minimize Damage

Little can be done to prevent or reduce the invasion of crops in the field by fungi. However, the following recommendations should help prevent storage fungi problems or minimize damage from storage fungi in stored grains.

1. Harvest as soon as the moisture content allows for minimum grain damage.
2. Adjust the harvesting equipment for minimum kernel or seed damage and maximum cleaning.
3. Clean all grain harvesting and handling equipment thoroughly before beginning to harvest. Clean bins or storage facilities thoroughly to remove dirt, dust and other foreign material, crop debris, chaff and grain debris.
4. Clean grain going into storage to remove lightweight and broken kernels or seeds as well as foreign material and fines.
5. Moisture content is by far the most important factor affecting the growth of fungi in stored grain. After harvest, grain should be dried to safe moisture contents as quickly as possible.
6. Aerate grain to safe and equalized temperatures through the grain mass.
7. Protect grain from insect and mite damage.
8. Check stored grain on a regular basis and aerate as needed to maintain low moisture and proper temperature.

6.3 Rodents in storage

Rats have been estimated to damage more than 1% of the world cereal crops and, in developing countries, estimates of 3-5% have commonly been reported. There are around 50 diseases which can be transferred to humans by rodents, including typhoid, paratyphoid, and scabies. In addition, rodents may be vectors of a large number of diseases affecting domestic animals. As rodents prefer food rich in proteins and vitamins and feed mainly on the embryo, they cause particular damage to the nutritional value and germination ability of seeds.

The three most important rodent species are:

- Black rat or House rat *(Rattus rattus)*
- Norway rat or Common rat *(Rattus norvegicus)*
- House mouse (Mus musculus)

There are also a number of species that are of great importance in specific regions:

- Multi-mammate rat *(Mastomys natalensis)* in Africa and the Middle East;
- Bandicoot rat *(Bandicota bengalensis)* in Southern and South East Asia;
- Pacific rat *(Rattus exulans)* in South East Asia, also occurring in Southern Asia

Their teeth characterize rodents. They have a pair of incisor teeth in the upper and lower jaws. The incisors are curved inwards and have an extremely hard anterior coating. The softer inside layer is worn down much more rapidly than the hard, outer layer. This means that the teeth are continually kept sharp, enabling them to damage even materials such as masonry and electric cables. The incisors do not stop growing. This means that the animals are forced to gnaw steadily in order to wear them down. Rats and mice cause losses in a number of ways.

1. Feeding on stored produce

Rats consume about 25 gm of food per day and mice eat approximately 3-4 gm per day. Besides eating stored produce, rodents contaminate a lot of the stored produce with urine, feces, hair and pathogenic agents. As it is extremely difficult to remove contamination, infested batches often have to be declared unfit for human consumption.

2. Damage to material and equipment

(e.g. tarpaulins, bags, pallets, sprayers) and to the store itself (cables, doors).

These often lead to subsequent damage:

- Produce leaking out of damaged bags or storage containers
- Bag stacks collapsing due to damage to the lower layers
- Short circuits leading to sparks or fire from cables being chewed
- Silos and warehouses may subside or even collapse as a result of being undermined
- Drainage canals around a store may be damaged.

Signs of rodent infestation

When there are signs of rodent infestation, it is necessary to conduct a thorough investigation of the store, its immediate surrounding area and neighboring land. There are a large number of clear signs of rodent infestation:

Live animals: Rodents are mainly active at night. If animals are nonetheless seen during the daytime, this is a sign of an already advanced stage of infestation.

Droppings: The shape, size and appearance of droppings can provide information as to the species of rodent and the degree of infestation. The droppings of Norway rats are around 20mm in length and are found along their runs. The droppings of Black rats are around 15mm long and are shaped

like a banana. Mouse droppings are between 3 and 8mm in length and irregular in shape. Droppings are soft and shiny when fresh, becoming crumbly and matt black or gray in color after 2 - 3 days.

Runs and tracks: Runs, such as those of Norway rats, are to be found along the foot of walls, fences or across rubble. They virtually never cross open areas of land, but always pass through overgrown territory, often being concealed by long grass. Runs inside buildings can be recognized by the fact that they are free of dust. The animal's fur coming into contact with the wall leaves dark, greasy stains. Even Black rats, which do not have any fixed runs, can leave similar greasy stains at points which they pass regularly, e.g. when climbing over roof beams.

Footprints and tail marks: Rats and mice leave footprints and tail marks in the dust. If you suspect there might be rodent infestation, scatter some sort of powder (talcum powder or flour) on the door at several places in the store and later check for traces. The size of the back feet serves as an indication of the species of rodent:

- Back feet larger than 30mm: Black rat, Norway rat, Bandicoot rat.
- Back feet smaller than 30mm: House mouse, Multi-mammate rat, and Pacific rat.

Tell-tale damage: Rats leave relatively large fragments of grain they have nibbled at (gnaw marks). They generally only eat the embryo of maize. Sharp and small leftovers are typical for mice. Damaged sacks where grain is spilled and scattered can be a further sign of rodent attack. Small heaps of grain beneath bag stacks are a clear sign. These should be checked for using a torch on regular controls.

Attention should be paid to damaged doors, cables and other material.

Burrows and nests: Depending on their habits, rodents either build nests inside the store in corners as well as in the roof area or in burrows outside the store. Rat holes have a diameter of between 6 and 8cm, whereas mice holes are around 2cm in diameter. These holes can be found particularly in overgrown areas or close to the foundations of a store.

Urine: Urine traces are fluorescent in ultraviolet light. Where available, ultraviolet lamps can be used to look for traces of urine.

Preventive measures

The most essential factors for the occurrence of rodents are:

- Sufficient supplies of food
- Protected places in which to build burrows and nests
- Hiding places
- Access to produce

Good store management and preventive measures taken as part of an integrated control program can help to deal with these factors.

Storage Hygiene and Technical Measures

- Keep the store absolutely clean! Remove any spilt grain immediately as it attracts rodents!
- Store bags in tidy stacks set up on pallets, ensuring that there is a space of Im all round the stack!
- Store any empty or old bags and fumigation sheets on pallets, and if possible in separate stores!
- Keep the store free of rubbish in order not to provide the animals with any places to hide or nest! Bum or bury it!
- Keep the area surrounding the store free of tall weeds so as not to give the animals any cover! They have an aversion to crossing open spaces.
- Keep the area in the vicinity of the store free of any stagnant water and ensure that

rainwater is drained away, as it can be used as source of drinking water.

Keeping Rodents Out

The requirements of preventive rodent control must be taken into account whenever new stores are being built. Particular attention should be paid to doors, ventilation openings, brickwork and the junctions between the roof and the walls. Repair any damage to the store immediately! This applies especially to the doors.