Cereal Grain Quality Losses in Sub-Saharan Africa

- Part 2 Reducing on-farm postharvest losses

Practical instructions for reducing cereal losses after harvest

Most postharvest losses in developing countries happened close to the farm, either in the field or at the farmstead. Those responsible for helping farmers reduce these losses often do not have easy access to advice on how to look after their grain. For this reason APHLIS is making available some advisory notes adapted from the UN World Food Programme's 'Training Manual for Improving Grain Postharvest Handling and Storage' (Hodges and Stathers 2012).

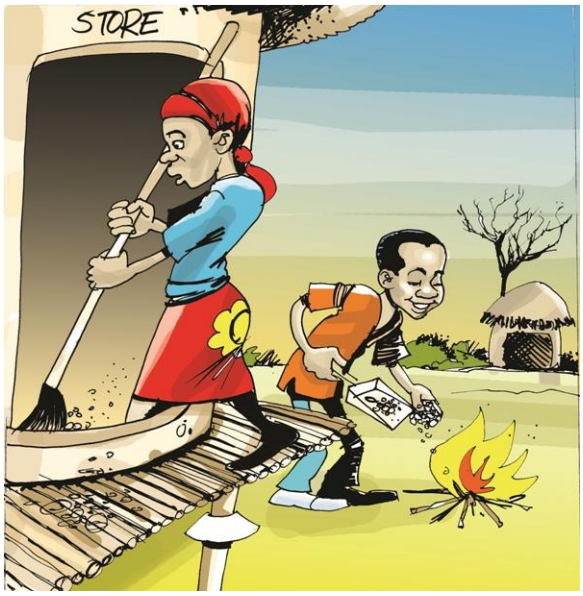
The notes can be used to help farmers to:

1. Prepare for the new harvest
2. Harvest on time
3. Harvest carefully
4. Dry the crop sufficiently
5. Thresh/shell the crop carefully
6. Clean the grain
7. Store the grain using an appropriate method
8. Using insecticides and other ways of killing insect pests in stored grain

1. Prepare for the new harvest

Before the new harvest is due it is important that farmers are already prepared for their postharvest activities. They must ensure that -

- the equipment needed for their harvest and postharvest activities is available and in good repair,
- they have decided where important activities will take place (allocating drying and threshing areas),
- there will be sufficient storage space for the crop,
- grain stores and sacks have been thoroughly cleaned before the new harvest arrives so that the residues of the old harvest (last season's crop) are removed from all cracks and crevices and either burnt or fed to animals (alternatively, they can be stored in a separate place and consumed quickly). Good hygiene is a very important activity to prevent postharvest losses, the new harvest should never be placed on, or with, grain from the previous season as this will encourage the movement of pests from the old to the new.



Sacks and stores need cleaning, good hygiene is an essential part of grain quality management

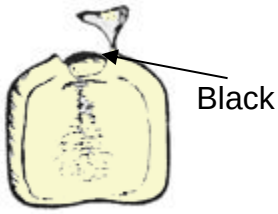
2. Harvest on time

It is recommended that cereal grains are harvested as soon as they are physiologically mature and then transported to the homestead for immediate drying. However, on reaching physiological maturity, cereal grains are still too moist and soft to be threshed so most smallholder farmers leave them to dry naturally in the field for several weeks prior to harvest; they are sometimes left on the stalks to dry in the sunshine or the stems are cut and arranged into piles called 'stooks'. This approach is generally not recommended as the crop left to dry in the field becomes more vulnerable to losses caused by several factors including infestation by insect pests and damage by birds, other wild animals and losses due to theft. The insects that attack at crop maturity may be carried over into storage and cause serious damage. For many crops there is an additional danger in late harvesting as the grain may start to scatter, this is especially the case for paddy rice, millet and sorghum. Late harvesting may also cause a problem as the fields need to be released for the planting of other crops. The only disadvantage of harvesting as soon as the crop reaches physiological maturity is that the crop will be heavier than if left in the field to dry for longer, so it requires more effort to move it to the homestead.

It is important to be able to recognise when crops are mature in the field.

Maize - the crop is mature when the plant has become straw coloured (light brown) and the grain hard, in the case of maize some of the cobs will droop downwards. Cob maturity in maize can also be tested by checking for the black layer that forms at the base of grains (where they connect with to cob). The layer can be seen by removing grains from the cob and scraping the base with your fingernail.

Mature maize crop with some drooping cobs



Mature maize grain showing black layer beneath the tip (that has been removed)

Sorghum and millet - grains tends to reach physiological maturity while the stalks and most of the leaves are still green but like maize the grains also develop a black layer at their base when mature. However, as the grain tends to mature from the top of the seed head downwards, the bottom of the seed head lags behind the tip by about one week, so it is worth checking grain from the top and bottom of the seed head for signs of maturity.

Paddy rice – the crop should be harvested when nine out of ten grains on the panicle are straw coloured, when they typically have a moisture content of around 20-25%; such grains are firm but not brittle when squeezed between the teeth.

3. Harvest carefully

Most smallholder farmers in developing countries harvest their cereal crops by hand and thresh them later. Maize cobs are plucked from the plant, while sorghum and millet heads and paddy rice panicles are cut. The harvested crop should be placed on clean mats, tarpaulins or directly into bags, this avoids contact with the soil which can lead to moisture uptake, staining from the soil and the transfer of fungal spores that can lead to fungal growth and mycotoxin production.

Harvesting in wet weather

If harvesting of maize is delayed due to wet weather then entry of water into the cobs can be reduced by breaking the stem just below the cobs and turning the cobs so that their tips are pointing downwards.

Harvesting in sunny weather onto a tarpaulin, mat or directly into a sack

If rain delays the maize harvest then turn cobs down by breaking stem just below cob so the cob hangs down to prevent water entering it

4. Dry the crop sufficiently

Drying the crop at the homestead is a better option than drying it in the field. During drying at the homestead the crop

1) should never be placed in direct contact with the soil, and
2) should be kept away from farm animals, otherwise the grain may be damaged or eaten, this may be done by tethering animals or fencing in the area where grain is drying.

For drying, millet and sorghum are usually left on the seed head and maize grain is left to on the cob. The reason for this is that in the unthreshed form, air can circulate more easily around the grain and so drying is more easily accomplished. By contrast, paddy is usually threshed before drying. In the case of maize, cobs may be dried either with or without husk cover; Box 1 suggests how to decide which is better for the specific situation.

Box 1 – Whether or not to dehusk maize cobs before drying

A careful decision has to be made as to whether the maize cobs should be dried with or without husk.

1. Dehusk maize cobs if
   a. Rapid drying is required
   b. There is no danger of cobs getting wet due to rain fall during drying (the husk provides some protection from rainfall)
   c. Storage period after drying will be short or the cobs will be shelled soon after drying.
2. Retain husk cover if
   a. Rapid drying is not essential
   b. There is a danger of cobs getting wet due to rainfall during drying
   c. Storage after drying will be at least 3 months (complete husk cover i.e. including the tip of the cob, provides some protection against insect infestation)

For drying, the crop can be placed directly in the sunshine on a drying floor that can be a cement area, a tarpaulin, layer of sacks or woven mats. Suggestions on how to use a tarpaulin or plastic sheet for drying are given in Box 2. In many places there can be cloudy weather and some rainfall at the time of drying so it is important to keep a watch on the drying crop and cover it with a tarpaulin prior to any rainfall. To make the process of drying quicker, cobs or seed heads should be placed in a single layer and turned at intervals of every hour. If they are placed in a deeper layer on the drying floor then drying will be slower.

If loose grain is to be dried, which is usually the case with paddy, then it should be at a depth of 2-4 cm and should also be turned at intervals of one hour or less.

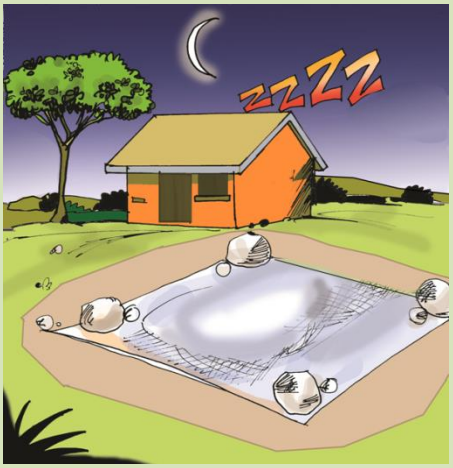
Laying the crop out to dry in a thin layer on concrete drying floor, tarpaulin or mats

Don't let drying grain get wet, cover with a tarpaulin if it is about to rain, or at night time

Box 2 Using the sun and some plastic sheeting to dry grain

- Find a large plastic sheet or several small plastic sheets or plastic sacks that can be laid out so that they overlap to form a large covered area.
- Build a flattened mound of hard-packed earth on which to place the sheet. If instead you use level ground, dig a shallow trench around the area on which the plastic will be placed to direct any rain water away from the drying floor.
- Make sure there are no sharp objects on the ground that will tear the plastic.
- Place the plastic sheets/ sacks on the place you have prepared.
- Put clean grain on the plastic, in a layer not exceeding 4cm deep.
- Stir the grain with hands, a rake or other suitable tool at least every hour so the grain will dry faster. Turning and stirring makes sure all parts of the grain are touched by air and sun.

- As the grain dries, moisture from the grain will collect on the plastic. After the grain has been drying for two hours, push all the grain to one half of the plastic sheet.
- Let the uncovered part of the plastic sheet dry off for 5 minutes or so.
- Then push all the grain back onto the half of the plastic sheet that is now dry and then let the other half of the plastic sheet dry for 5 minutes, before re-spreading the grain out over it.
- The plastic sheet should be aired in this way every two hours during drying.
- Cover the grain at night. Push all the grain onto one half of the plastic sheet and fold the remaining plastic over it as a cover, or place an extra piece of plastic over the grain. Put boards, planks, rocks, or other heavy things on the corners and edges of the plastic cover to keep it from blowing off during the night.



- How fast the grain dries using this system depends on the weather, how hot and dry it is, and how moist the grain is at the start. Starting with grain at 20% moisture content and with 5 hours of sunny dry weather daily then the grain can be dry enough for storage in two or three days.

A drying floor is not the only way to dry grain on farm, it may be more convenient to place the crop on drying racks or in a specially constructed drying crib (Box 3). Drying cribs are commonly used for drying maize but may be used for other crops. The cribs recommended for drying are long and narrow, with wooden slats or chicken wire sides that allow free ventilation and a roof that protects against rain. The legs are best supplied with rat guards that will keep rodents out. The cribs are built across the prevailing wind to promote drying.

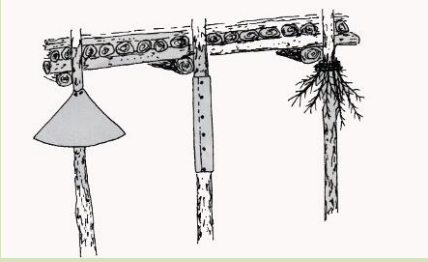
A drying crib

Box 3 – Important features of drying cribs

Ideally drying cribs are rectangular with a framework of wooden poles, erected in the open with the long side across the prevailing wind. This will ensure good ventilation for drying. Grain dries better in a narrow crib because air passes through it more easily. The maximum width of a crib is determined by the prevailing climatic conditions. To ensure that maize dries sufficiently and mould spoilage is avoided the maximum width should be as follows -

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

The walls of the crib can be made of raffia, bamboo, poles, sawn timber, or chicken wire. At least half of the wall area should be open to ensure good ventilation. Roofs can be of thatch or corrugated iron sheet. To protect from rodent attack the legs of the drying crib should be fitted with rodent guards. These prevent rats climbing up the legs, and the floor of the crib should be at least 1m above ground level, beyond the maximum distance that rodents can jump. It is important to ensure there are no trees, plants or structures close enough to the crib that would allow rodents to jump across and into the crib.



A selection of rodent guards

Cribs are multifunctional, they are primarily used for drying and have the advantage that if used to hold early harvested maize cobs then losses during field drying will be lower and the land can be cleared and prepared earlier for a new crop. They can be used to store shelled grain in sacks if the walls of the crib are covered with mats to protect grain from driving rain.

The open structure allows for easy cleaning and for periodic inspection of grain quality.

Loading and emptying is relatively easy through the open framework or through a door in the end wall.

Farmers should clean the crib very well prior to each harvest season, and should check to ensure none of the timbers are infested by storage insects, especially larger grain borer. If so then those timbers should be replaced, otherwise the pests will just move directly into the freshly harvested drying grain.

If maize cobs, or other unthreshed grains, are to be stored for extended periods (>3 months) in a drying crib, or elsewhere, it may be necessary to treat them with an insecticidal dust to limit insect damage. Maize cobs (with or without husk cover), or other grains that are stored unthreshed for example millet and sorghum seed heads, can be treated by applying insecticidial dust in layers as the unthreshed grain is loaded into a store or crib. See Section

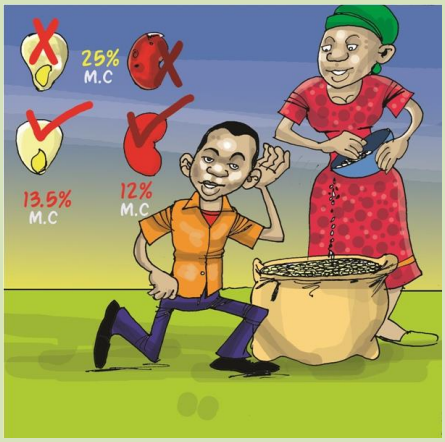
It is possible to organise grain drying collective, at the level of the Farmer Organisation. In this case, artificial drying facilities such as forced air ventilation or hot air dryers could be used to give rapid and reliable drying. However, these facilities require considerable investment and have maintenance and energy costs. Before embarking on this type of drying the economic feasibility needs to be established.

5. Knowing when the grain is dry

Farmers need to judge when grain drying is complete, that is when cereal grains reach a moisture content of 14% or less and for beans may be as low as 12%. Experienced farmers will know how to judge the safe moisture content; evidenced by the fact that they have been storing grain safely all their lives. For details of how to check grain moisture content, read Box 3.

Box 3 – How to check grain moisture content

Farmers need to know when their grain is dry enough for safe storage, i.e. at a moisture content of 14% or lower for cereal grains. The grain gets harder as it gets drier so that with experience farmers can tell by biting or pinching it, or by the different sound it makes when pouring or rattling it. These methods are subjective and of no use if the farmer is not experienced.



A more objective approach is to use the 'salt method', this is quick and easy but will only indicate that grain is above or below 15% moisture content. Dry salt will absorb moisture from grain. This principle can be used to help determine whether a grain sample has a moisture content of above or below 15%.

Materials required:

- A clean dry glass bottle of about 750 ml capacity, with a cap that makes it airtight.
- Some common salt

How to do it:

It is important first of all to make sure the salt is dry. Place the salt in hot sun in a thin layer on some plastic sheeting, until the salt is hard at least 3 or 4 hours. Turn the salt at intervals during this time. Alternatively this can be done for a much shorter period in an oven. Store the dry salt in a sealed container

Fill one third of the dry bottle with the grain sample (250g to 300g).

Add 2 or 3 table spoons of salt (20g or 30g).

Close the bottle tightly with its cap.

Shake the bottle vigorously for 1 minute.

Leave the bottle to rest for 15 minutes.

If after 15 minutes the salt sticks to the side of the bottle then the moisture content of the grain is above about 15% and so is not safe for storage. If the salt does not stick to the bottle then the moisture content is below 15% and so is safe for storage.

Otherwise the only alternative is to ask someone with access to a moisture meter and who has been trained in how to use it to test grain moisture content.

5. Thresh/shell grain carefully

Threshing or shelling is the process of separating the grain from the seed heads, panicles, or cobs. It is important to minimize the damage done to grain during this process as damaged grain is much more prone to attack by insects and fungi. Consequently, techniques that crush and damage grains such as beating with sticks or trampling by cattle, are not recommended. Also, the grain should be neither too moist (soft) or too dry (brittle) at the time of threshing; it is best done when grain is around 14 to 16% moisture content, although paddy rice is commonly threshed at around 18-20%.

Beans, sorghum and millet seed heads and paddy panicles can be threshed/shelled by hand and this can be done conveniently by beating the crop against a threshing platform that has high sides that prevent the loss of grain. However this process is slow and tedious. A relatively expensive alternative would be tractor or motor-driven threshers, there are many different models with outputs ranging from 600 to 5000 kg/h. Most models will also clean the threshed grain using shaking screens and/or blower fans. In the case of paddy rice, pedal operated threshers are also commonly available.

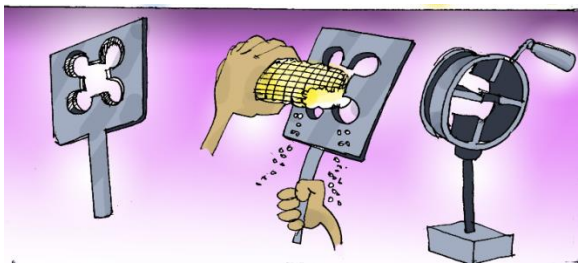
Threshing platorm for manual threshing of beans, sorghum, millet, rice

To shell maize, the cobs must first of all be dehusked. At this stage it is important to select out any cobs that are insect or mould damaged since the grain from these cobs would reduce the quality of the other grain if they were mixed.

Dehusking the maize cobs and discarding any that are damaged

Maize cobs may be shelled using bare hands, this is slow and is relatively painful when large amounts are done at one time. An alternative is to use wooden or metal hand shellers, where one hand is used to hold the cob and the other rotates the sheller around the cob to strip off the grain. These are tedious to use and have never achieved widespread popularity. Hand-cranked or pedal operated shellers are available in a range of models and typically

give outputs of about 50-130 kg/hour. For large-scale production a range of different models of motor-driven shellers are available powered by electricity or diesel. In Uganda, farmers groups and grain traders alike have identified the adoption of motorized maize shelling as the single largest contribution to the recent improvement in grain quality, it gives a product that has fewer broken grains and because the process is quicker so more time is available for farmers to devote to ensuring better quality. In many places, motorized maize shelling is now being offered as a service by private entrepreneurs with mobile machines.

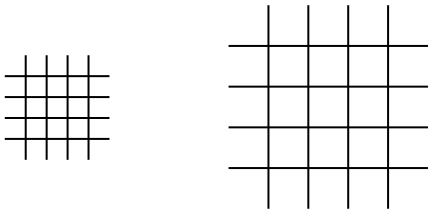


A hand-sheller and a hand-cranked shellers for maize

A motorised maize sheller

6. Clean the grain

Cleaning grain can substantially improve its quality and hence its grade and price. Cleaning involves the removal of foreign matter such as stones, plant material from harvesting such as husks, etc and broken grain and dust produced during threshing. At the same time it is possible to remove insect damaged and mouldy grains by hand picking. Cleaning is often done manually by winnowing. This involves tossing the grain into the wind which carries off the lightest impurities, while the heavier grains falls onto a mat. However, this does not separate the heavier impurities. For this a sieve is required, where the grain is retained on the sieve and smaller heavier impurities fall through it. Such a sieve can be either single or double handed. The double handed sieve can be operated by two people, who rock it back and forth. The mesh sizes of sieves varies according to the size of the grain being cleaned but typically for maize and beans a 4.5mm mesh is used and for sorghum 2.0mm and for millet usually even smaller.



A 2mm mesh and a 4.5 mm mesh

Winnowing grain to remove light foreign matter

Using a two-handed sieve to remove broken grain and foreign matter

Cleaning can be automated and threshing machines often also incorporate a mechanical blower used for winnowing the grain. It is important to ensure that such machines are kept clean, to prevent them acting as a source of insect infestation.

7. Store grain using appropriate methods

Once grain is sufficiently dry and cleaned it should be put in storage. In all cases, the moisture content of grain placed in store must be at or below the safe limit (see Section 4 Box 3). Grain may be stored on farm for different length of time as follows -

- short-term (e.g. <3 months) before it is moved to the next link in the marketing chain, in this case the Collection Point of the Farmers' Organisation, or

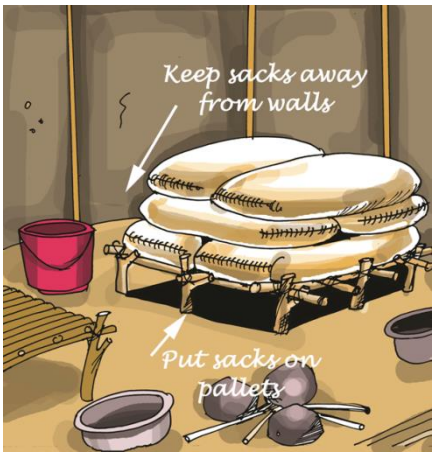
- medium to long-term (3-12 months) where farmers keep it for household consumption or for sale at a time when prices are more favourable.

There are many options available to farmers for storing their grain and protect it against pest attack. Some of these options are presented in Table 2; note that the costs indicated in the table are only a rough guide and will vary from situation to situation. Table 2 can be used to help decide on the most appropriate store type and its associated means of preventing pest attack. You can experiment with the different options to find which best suits your needs and budget. The remainder of this section describes in more detail the options suggested in Table 2.

Storage in open weave sacks

For marketing or keeping grain on farm for periods of three months or less, open weave sacks are the most convenient option. Sacks may be made of either polypropylene, jute or sisal. The choice of bag size should meet the requirements of the Farmers' Organisation. Typically, 50kg bags are favoured since these are more easily handled than say 100kg bags; most 50kg bags are made of open weave polypropylene. If second-hand bags are to be used then they must be thoroughly cleaned before use, this is most easily done by plunging them in boiling water and then allowing them to dry, before filling with grain. The bags should not be overfilled with grain, after filling they should be closed by hand stitching or by using a stitching machine. Before stitching, fold the mouth of the bag inwards by 5 to 10 cm, this creates a valve that helps to prevent grain being forced out of sacks when they are piled on top of each other. A 50kg bag should have at least 16 stitches across their width, larger bags proportionally more.

Before delivery to the Collection Point, the sacks of grain should be kept in a secure location, such as in the house. The sacks must be prevented from making contact with the floor or walls of the house, from which they might absorb moisture, causing the grain to rot. To do this the bags are placed on pallets made of sticks and/or stones so they are suspended at least 12 cm above the floor (no pallets can be constructed then a plastic sheet could be used) and away from contact with the wall. The roof above them must also be in good conditions so they don't get wet from leaking rain water.



Sacks in a house placed on a pallet made of sticks, with good clearance from the walls

If maize or sorghum grain or beans are stored in open-weave sacks for periods exceeding 3 months, then there is a danger that insect infestation may cause significant damage, this is less likely in the case of millet, due to its small grain size and storage at moisture contents that are very limiting to insects (e.g. 10% or less), or in the case of paddy that has a seed coat that is difficult for insects to penetrate. To avoid such damage, maize, sorghum and beans that are to be stored for more than 3 months should be admixed with a suitable insecticidal dust at the manufacture's recommended dosage rate (Box 6).

Insect-proof and hermetic stores

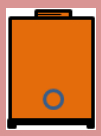
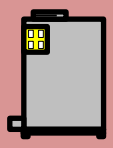
Besides open-weave sacks there are a variety of other store types that can be used to keep grain in the house. The efficient types are insect-proof and, even better, they may shut so tightly that they are also airtight (hermetic).

Insect proof- means that the store shuts tightly enough that insects can't enter. If the grain is not already infested when it is put into this type of store then the grain will remain free of insect infestation during the period of storage.

Hermetic – means that the store shuts so tightly that neither insects nor air can enter. When hermetic stores are filled with grain and closed, the oxygen in the store is gradually depleted and the concentration of carbon dioxide increases. This happens due to the biological activity of the grain and any insect pests that are present will be killed. This is very convenient since pest control can be achieved without the use of insecticides that might otherwise have to be purchased.

It is important to remember that insect-proof and hermetic stored should not be place in the sunshine or close to the fire. If this happens then one side will get hotter than another. This could lead to moisture condensation on the cold side. This would lead so some grain becoming rotten. So keep such store in well shaded areas away from fires.

Table 1: Comparison of store types for safe storage of grain in smallholder households

Store type	Storage period	Pest control	Weaknesses	Costs US$ / kg	Life span	Cost/ tonne/ year
Open weave sacks (jute, sisal, polypropylene) 	0-6 months	If >3 months storage then admix insecticide (Section 5.12.1). For cowpea an option is to use solarisation if this is not for seed (Section 8)	If used >6 months, grain quality declines more rapidly than in other store types	0.1t unit US$ 0.03	3 years	US$10 (+ pest control costs)
Improved mud silos 	3-12 months		Shorter life than metal silo, very heavy so can't be moved to new location, takes up fixed space in house whether empty of full	1t unit US$0.1/kg	5 years	US$20 (+ pest control costs)
Metal silos 		1. Make hermetic then use lighted candle or phosphine fumigation, or 2. Admix insecticide (Section 8)	Extra sealing required to make hermetic, then no access for 2 weeks.	0.18t unit = US$0.41/kg 1.8t unit US$0.18/kg	15 years	US$27.4 (+ pest control costs) US$12.4 (+pest control costs)
Polythene bags (1 liner + sack) 		1. Solarisation if grain not for seed (Section 8) 2. Admix insecticide (Section 8)	Best for small quantities, susceptible to sharp objects and rodent attack.	0.05t unit US$0.045/kg	2 years	US$22.5
Metal/plastic drums 		Hermetic seal kills pests	Drum to be nearly full and no access for first 6 weeks of storage.	0.15 t unit US$0.26/kg	20 years	US$13.4
Triple bags (2 liners + 1 sack)			Susceptible to sharp objects and rodent attack. No access for the	0.05t unit US$0.06/kg	3 years	US$20

			first 6 weeks of storage.			
SuperGrain bags (1 liner + sack) 				0.05t unit US$0.065/kg	2 years	US$32.5

Store types =	**Unprotected**	**Insect proof**	**Insect proof and hermetic**

Pest control advice
Box 5 Admixture of insecticidal dust to shelled grain

Insecticide dusts are recommended for use by smallholder farmers because they -

- contain a low concentration of insecticide, making them safer to handle than more concentrated formulations
- are ready to use
- are supplied in small packets making the calculation of dosages easier

The instructions on the packet will tell you

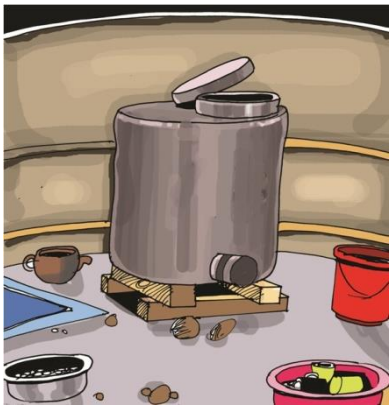
- how much powder to use, and
- for which crop the insecticide is suitable (cereal grain, grain pulses or both) and for how long it will provide protection against insect attack.

Admixing an insecticidal dust with grain is a simple process that involves treating one or two bags at a time. The grain needs to be removed from the sack and placed in a heap on a clean surface. The insecticide is added to the grain and it is then repeatedly mixed in using a shovel. All the details of this process, including how much to add and essential safety precautions can be found in Section 8.

Making a heap of grain to which the insecticidal dust is added.

Shovel the grain between two places until the dust is evenly mixed in

Some insect proof or hermetic stores are made of metal. If these make contact with the ground then the moisture from the ground may result in corrosion. It is there for important to raise them up from the ground by placing them on palleting.



Insect-proof and hermetic stores should be raised off the ground and placed inside a shelter so they are completely shaded from the sun

Farm stores that are insect-proof

Metal silos

Metal silos are insect-proof but can be made hermetic by tying rubber from a bicycle inner tube very tightly around the grain input and output ports. In order to have a quick change in gas composition, a lighted candle may be placed on the grain surface at the time the inlet and outlet ports are sealed (do not do this with plastic grain stores as they may catch fire). The candle will burn the oxygen and in so doing create carbon dioxide, this will extinguish the candle and within two weeks will kill any insects that are present. Do not open the silos until after two weeks as this will let in fresh air and the insects will survive. Alternatively, sealed metal silos can be fumigated with phosphine gas (generated from aluminium phosphide tablets) but this may not be a practical option as in many countries farmers are prohibited from purchasing and using the tablets or simply do not have access to them.

Single layer polythene sacks

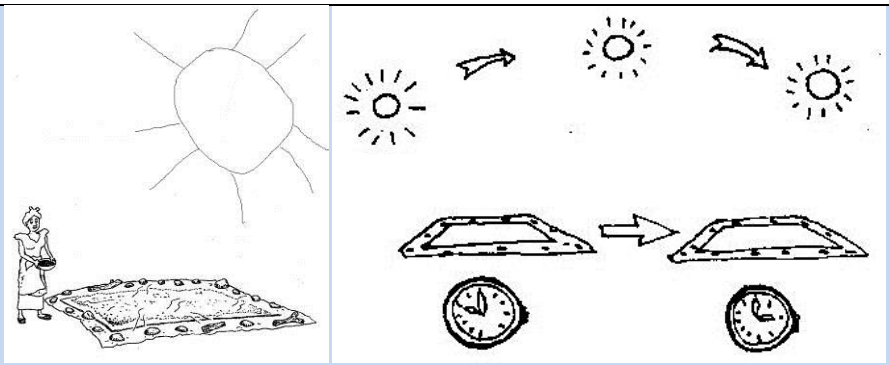
Polythene sacks (continuous sheet not open weave) can be used to store grain that is at a safe moisture content. The bag should be tightly shut by twisting then folding over the mouth of the bag and tying it shut with string (the same way as shown in Box 9). This will prevent the entry of insects (so this store is insect-proof) but a single layer polythene bag is still fairly permeable to the gases in air, so they are not hermetic. This means that when the bag is shut the gas composition does not change sufficiently to kill any insects that may be present. If this is desired then hermetic bag types such as the SuperGrain bag or Triple bag (Table 1) should be used but these are more expensive options. To prevent insect infestation in the single layer polythene sack then grain (especially cowpea) may be solarised before storage (see Box 6) alternatively insecticidal dust may be admixed (see Box 5). Polythene bags are not very strong and holes may be made in them by sharp object or by rodents. To give them further protection it is best to place them in an open weave polypropylene bag, that way there will be two layers of protection. This will involve extra expense but this will be repaid by the long life of the bag and reduced failure rate.

Improved mud silos

Improved mud silos, typically have a concrete base and concrete top with the cylinder between the base and top made of mud. As mud is porous, mud silos are not hermetic but when sealed are generally insect-proof. They can therefore be used as good stores but for storage periods exceeding three months the grain should be admixed with an approved insecticidal dust at the recommended dosage rate (see Box 6) or solarised (see Box 7).

Box 6 Pest control advice - Solarising grain to kill insect pests

When grain is placed in a solar heater, it may be heated sufficiently by the sun to kill all insects, a process called solarisation. This is usually done with relatively small quantities of cowpea (25 to 50kg), since it is labour intensive, but it could also be done with other grain. The process can reduce the viability of seed so it is better only to use it for food grain. The simplest type of solar heater consists of an insulting layer on which grain is laid to a maximum depth of about 2-3 cm, they are then covered with a sheet of translucent plastic and the edges of the sheet are weighed down with stones or other heavy items. The solar heater should be kept in the sun for at least 5 hours. After solarisation the grain should be allowed to cool before it is placed in store. If the grain is placed in an insect-proof container (see Table 2.1) then it will remain free of infestation. If there is free access to insects (e.g. in an open weave sack) then after 2-3 months the grain may become reinfested. To avoid this, the grain should be retreated each month. So if the grain was solarised on the 1st of June, then it should be solarised again on 1st July. More details of solarisation are given in Section 8.



Grain being solarised in a thin layer. Beneath the grain there is matting and a layer of jute sacks while on top there is a clear plastic sheet. The grain is held like this in the sun for 5 hours.

Farm stores that are both insect-proof and hermetic

Metal/plastic drums

Plastic and metal drums that close so tightly that they are hermetic, make very good stores. These need to be more or less completely filled with clean dry grain, to displace as much air as possible before closure. The drums are then kept tightly shut for at least six weeks. During this time the oxygen will be depleted and the carbon dioxide rises so that any insects present will be killed. If old oil drums are to be used then they must be thoroughly cleaned (Box 7)

Box 7 Important tip for using old oil drums

If metal drums are old oil drums then before use as grain stores they must be very thoroughly cleaned using a mixture of water, detergent and sand. Fill the drums with this mixture and roll them, leave for one day and repeat two more times. After that wash out with clean water and leave to dry. Make sure that after this process there is no smell of oil, otherwise repeat the process until there is no smell.

Hermetic plastic bags

Some plastic bags are hermetic, these are the ‘triple bags’ and ‘Superbags’. As with metal silos and metal/plastic drums, grain you are going to consume or sell in the next six weeks should not be put in hermetic plastic bags and, as with all stores, the grain should be at most 14% moisture content when entering storage. The use of hermetic plastic bags is described in Box 8.

Box 8 - Hermetic storage in plastic bags

Plastic bags can make good grain stores but must be kept safe from rodents that might make holes in them and so break the seal. Occasionally, insects may also make holes in plastic bags.

Triple bagging
The triple bagging is widely used for the storage of cowpea, but could be used for other pulses and cereals. There are two inner bags made of 80 micron polyethylene and one outer more durable bag to help protect against damage. The first bag is filled with grain at a safe moisture content for storage which is tied shut securely using string. The first bag is placed within a second bag and this is closed securely. A third bag is used to enclose the first two and to protect against damage; the third bag can be made of open weave polypropylene. It is recommended that the two inner bags are made of clear plastic so that the grain can be easily seen for any signs of insect attack. The bags should remain sealed for at least six weeks after they are filled and after opening they should be resealed quickly to prevent entry of pests. Triple bagging is easily adopted by farmers, provides a very high level of insect control, and the bags may be used for as long as 3 years before they become too damaged and so need to be replaced.

Triple bags being prepared

Superbags
Hermetic sacks (e.g. GrainPro Superbags) are made of a multi-layer polythene material that incorporates a gas barrier that restricts oxygen and water vapour movement. These hermetic sacks are made in a variety of sizes that can hold 50kg to 3 tonnes of grain/seed. It would be normal for a farmer to place a 50kg the Superbag in an open weave polypropylene or jute bag to give it some protection and so extend its life. Studies with paddy rice stored in Superbags has demonstrated that farmers are able to maintain seed germination viability for a much longer periods, control grain pests without using chemicals and maintain grain quality for a longer period. Superbags are being traded in Africa.

A summary of the important points to remember when using insect-proof/hermetic stores

There are a number of general recommendations and important consideration when using insect-proof/hermetic stores. These are listed in Box 9.

Box 9 – Important points to remember about using insect proof/hermetic stores

1) Grain you are going to consume or sell within six week of harvesting should not be put in the sealed store but can be stored in open weave sacks and does not need to be treated with a grain protectant such as an insecticidal dust (as few if any insects will develop in this short time).
2) When putting grain in well sealed or hermetic stores it must be at a safe moisture content (typically 14% or less – Section 4).
3) You must check to make sure the store has no holes in it and it is properly closed.
4) The hermetic stores must remain fully sealed for at least six weeks if the farmer is relying on natural deoxygenation, but in the case of metal silos where a lighted candle has been used to deoxygenate the store then it should be kept closed for at least two weeks.
5) The store should be located inside the house (or at least completely shaded from the sun) and not near a fire. It is important that the store does not get too hot. If the store gets too hot on one side and remains cool on the other then there is a danger of moisture migration, this could lead to condensation on the cold side. Condensation of water on grain can lead to mould damage. Furthermore, if the grain is to be used as seed then its viability will be lowered if it is subjected to higher temperatures (especially if over 30°C).
6) It is better to keep any metal stores store off the floor as they may become damp and this would lead to corrosion. Place the metal store on a wooden or brick platform and this will prolong their life.

10 Using insecticides

Admixing an insecticidal dust with threshed grain

If maize or sorghum grain are stored in open-weave sacks for periods exceeding 3 months, then there is a danger that insect infestation may cause significant damage. To avoid such damage, the grain should be admixed with a suitable insecticidal dust at the manufacture's recommended dosage rate.

Insecticide dusts are recommended for use by smallholder farmers because they -

- contain a low concentration of insecticide, making them safer to handle than more concentrated formulations (such as emulsifiable concentrates)
- are ready to use
- are supplied in small packets making the calculation of dosages easier

The instructions on the packet will tell you -

- how much insecticide dust to use,
- for which crop the insecticide is suitable - cereal grain, grain pulses or both, and
- for how long it will provide protection against insect attack.

Well designed insecticide containers will have a date stamp, an indication of shelf-life, and supply the insecticidal dust in an amount relevant to the measures of grain used by farmers. The packets usually contain sufficient powder to treat one or two bags of grain. Insecticides must be applied at the recommended rate of application stated in the instructions. If too little is used it will be ineffective. If more than the recommended amount is used then it is wasteful, it will not kill more insects and the grain may not be safe to eat. Finding out how much dust to add to the grain is explained in Box 10.

Important – the following issues must be considered when advising people on the use of dilute insecticides for the protection of stored grain:

- **Use only insecticide powders that are labelled for use in mixing with food grains. Dust labelled only for treatment of seed grain should NEVER be mixed with grain intended for food.**
- **If grain is going to be consumed within three months there is probably no advantage in applying the dust (Section 7, Table 1); it is recommended that you do not. Generally, the grain to be treated will be that for storage longer than three months and is likely to be the grain kept for household consumption.**
- **If the grain is already infested with insects it is wise to consume it quickly, there is probably little if any advantage in applying any insecticide.**
- **Although it is safe for farmers to apply insecticidal dusts by themselves, it is wise to avoid breathing in the dust so a simple precaution such as tying a handkerchief across the mouth could be taken.**
- **It is wise to wash hands after applying the dust.**

Pest control advice
Box 10 – How much insecticidal dust to apply to grain

When treating grain with an insecticidal dust you must follow the instructions given on the insecticide container (usually a packet or plastic bottle). So for example, a packet might contain the correct amount of dust to treat a sack of 50kg, 90kg or 100kg of grain or whatever weight of sack that is commonly used.

Normally, you will be told the number of kilograms of grain that can be treated with all the dust in the container e.g. “This packet holds enough dust to treat 100kg of grain”. In this case, if you have only 50kg of grain then you should only use half the dust in the packet. If you have 200kg of grain you will need two packets etc.. In general you can find out how many packets of insecticide are need by using the following equation -

$$\text{Number of packets of Insecticidal dust required} = \frac{\text{Number of kg of grain to be treated}}{\text{Number of kg of grain treated by one packet}}$$

So for example if each packet of insecticide was sufficient to treat 100kg of grain, and there was 250kg to treat then

$$\text{Number of packets} = \frac{250}{100} = 2.5 \text{ packets}$$

Farmers themselves may already use traditional grain protectants but these are not recommended for grain that is going to be supplied to a high quality market (Box 11).

Pest control advice
Box 11 - Grain preserved with traditional protectants may be good for home consumption but should generally be avoided for commercial quality grain

Smallholder farmers in many parts of the world use traditional grain protectants to prevent insects attacking their grain. These protectants include ash from the fire and a variety of plant materials that have insecticidal properties. These are admixed with the grain, typically in quite high proportions. If households have a traditional method of treatment that they believe works well for them then they should be encouraged to use it to protect the grain that they will consume themselves. However, for collective marketing it is unlikely that grain treated with traditional protectants would be acceptable, as its quality will be diminished. For

example admixture with ash often leads to some discolouration of the grain and use of plant materials some non-grain odours and the presence of foreign matter.

11. Admix an insecticidal dust to shelled grain

Admixing an insecticidal dust with grain is a simple process that involves treating one or two bags at a time. The process is as follows:-

1) You will need a shovel and enough insecticidal dust to treat your grain. Read the instructions on the packet of insecticide very carefully so that you add the correct amount of insecticide to the grain (Box 10 explains how to decide how much insecticidal dust to apply).

2) Make a heap of the grain on a clean concrete floor, tough plastic sheet, tarpaulin or metal sheet (not on bare earth)

3) Open the packet of insecticide and sprinkle the correct amount of powder all over the heap of grain, making sure the wind does not blow it away.

4) Using a clean shovel, gently mix the powder into the heap as well as you can.

5) Shovel the heap to another part of the clean plastic sheet/ tarpaulin/ concrete floor

6) Then shovel it back again.

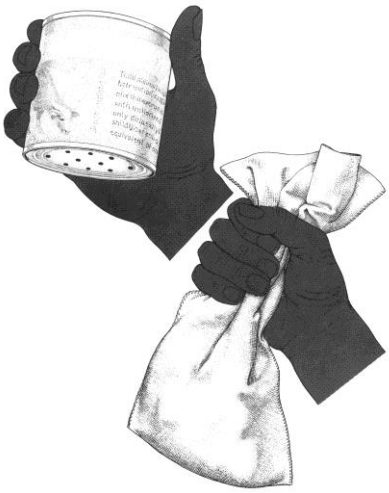
7) Then shovel it back again for a third time.

8) When you have finished, you should not be able to see any patches of insecticidal powder, and all the grains should be coated in a thin layer of powder. Using your shovel carefully load the grain back into a storage structure or sacks.

12. Admixing insecticidal dust with maize cobs

If maize cobs are to be stored for extended periods (>3 months) in a drying crib, or elsewhere, it may be necessary to treat them with an insecticidal dust to limit insect damage. This section explains how this is done using what is called the 'sandwich method', that can be used to treat maize cobs (with or without husk cover) or other grains that are stored unthreshed, for example millet and sorghum seed heads. The treatment of cobs is only recommended if the maize cannot be shelled and treated with insecticide (this is because, shelling and treating is better as it requires less insecticide and insects are controlled better).

Insecticide dusts should be applied evenly. The best way to do this is to apply them using a sprinkler made from a tin can or a piece of sacking. Insecticide applied from the tin or bag by gentle shaking will settle as a fine layer of dust on treated grain or store surfaces.

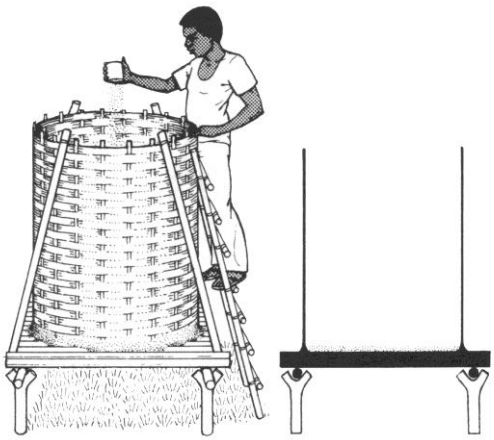


A tin or bag sprinklers can be constructed as follows:

- The tin can sprinkler can be made using a clean tin with a tightly fitting lid. About 10 holes should be made in the lid of the tin using a 5 cm nail or similar pointed tool.
- The bag sprinkler is made from a piece of old jute or sisal sacking (60 cm x 40 cm), fold the sacking in half and then stitch the open sides to make a bag. Place the dust inside the bag and it will then come out through the open weave when the bag is shaken.

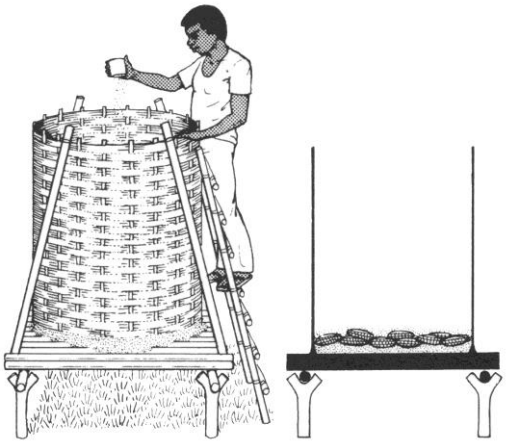
The following technique should be used for applying dilute dust by the sandwich method:

1. Clean the store and remove all old maize cobs, maize grain and rubbish
2. Work out how much insecticide will be needed to treat the maize according to the manufacturer's recommendations (see Box 12).
3. If the maize cobs are not dehusked before storing, remove any cobs that have poor husk cover or show signs of damage. Store only clean cobs with good husk cover.
4. Sprinkle some insecticide over the storage platform or the walls and floor of the store.

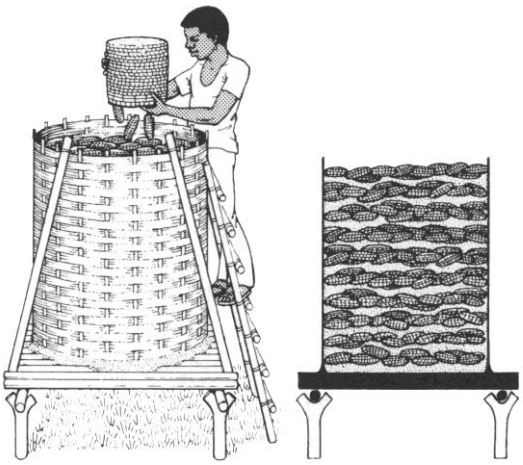


5. Stack a layer of cobs in the store.

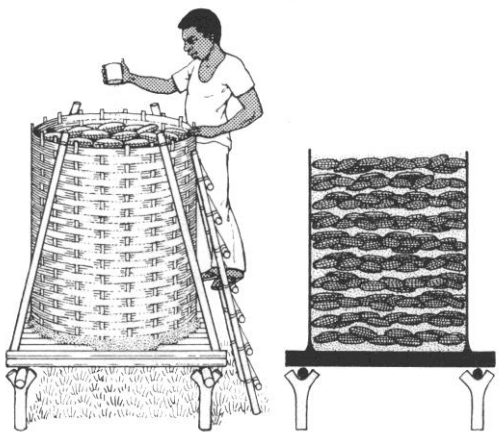
6. Sprinkle insecticide powder evenly over the surface so that cobs are covered with a fine layer of powder.



7. Put another layer of cobs on top of the first and apply powder as before.



8. Continue filling the store with layers of cobs sprinkled with insecticide powder until all the cobs are stored or the store is full.



9. Finally sprinkle insecticide powder on the top layer of cobs and close the store in the usual way.

10. If the cobs are stored on a platform in the open, cover the stack with a thatch or iron roof.

Pest control advice

Box 12 – Admixing an insecticidal dust with maize cobs - dosage calculation for the sandwich method

In the sandwich method, the same dosage is applied as for an admixture of insecticide with grain (Box 10). The amount of insecticide applied is calculated on the basis of the weight of stored produce, which is given in the manufacturer's instructions written on the insecticide container e.g. "Add 50g of dust to 100kg of grain".

For each layer, maximum thickness of 20 cm, the corresponding amount of insecticide is calculated according to the weight of the layer. Care must be taken to have layers of the same thickness. It is recommended to retain about 10% of the calculated quantity of insecticide to treat the floor and walls of the storage container prior to filling, and the top of the storage container at the end of filling. When storing the produce on platforms, retain a part of the insecticide from each layer to dust the outside of the stack once all the produce has been put into storage.

Example: Maize cobs are to be treated using a dust formulation, with a recommended application rate of 50 g dust /100 kg of maize.

2 baskets of maize cobs make up one layer and the cobs in each basket on average weigh 60 kg.

The overall weight of the first layer is thus: 2 x 60kg= 120 kg.

The amount of dust formulation required to treat the first layer (120kg maize), including floor and part of the wall, would be: 50g / (100kg/120kg) = 50g / 0.833 = **60g**

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

Farmers often have difficulty in knowing how much insecticide dust to add. It is best for an extension worker to tell farmers how much insecticide needs to be added for each unit of produce. This is commonly done by expressing the treatment as the number of match boxes full of dust per unit (sack, basket, tin).

13. Solarisation to kill insect pests

The process of heating grain in the sun to kill insects is called solarisation and is summarised in Box 13. This process is usually done with relatively small quantities of cowpea (25 to 50kg), since it is labour intensive. It is also normally applied to grain being kept for food rather than for seed it as may reduce seed viability. Solarisation may be extended to cereal grains using the method described below or more sophisticated larger-scale solarisers.

Pest control advice
Box 13 – Solarising grain to kill insect storage pests

Solarization is a process of holding grain at a high enough temperature for long enough so that any insects present will be killed. This is different from drying as the grain will be placed in a solar heater (for example covered by a plastic sheet), this reduces air exchange and so limits drying. Solarisation is labour intensive so that it may be appropriate for relatively small quantities of grain, for example 25 to 50kg. For this reason it has been promoted for the treatment of cowpea, which farmers have in much smaller quantities than cereals.

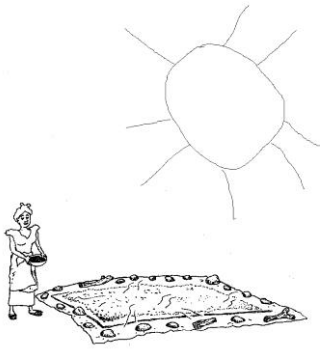
If cowpea is held at 65°C for about five minutes then all life stages of bruchid beetles can be killed, but if held at 57°C then all stages can be killed in about 1 hour. To achieve lethal temperatures pulses need to be solarised in a solar heater –this can be as simple as placing the cowpea on an insulating layer, covering them with a sheet of translucent plastic and weighing down the edges with stones. The solar heater is kept in the sun for at least 5 hours and will kill all insects. However, if the cowpea are to be used as seed for planting this may not be an appropriate procedure as there is some evidence that it can reduce germination rates by up to 20% but this may vary according to variety. An alternative to plastic sheeting is to use a solar heater constructed from corrugated galvanised iron, this can be used for larger quantities and is more durable than plastic sheeting so may be a more cost effective option in large-scale operations. The larger-scale option may be appropriate for the treatment of cereal grains.

Heat treatments need not necessarily be delivered by sun light. In some places cowpea are heated on metal plates over the fire but such treatment can result in scorching which may be an unacceptable reduction in quality. A possibly more acceptable method would be to treat cowpea with steam. Preliminary studies in Ghana have shown that steaming of small lots of cowpea at 98°C for 5 to 15 minutes make the cowpea more or less resistant to the bruchid beetle *Callosobruchus maculatus*. It seems that the process hardens the seed coat and reduces water absorption properties but does not modify the cooking or processing characteristics. This technique may not work for all varieties of cowpea.

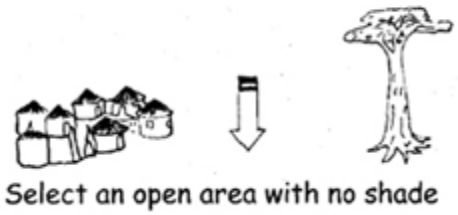
The simplest type of solar heater consists of an insulting layer on which grain is laid to a maximum depth of about 2-3 cm, they are then covered with a sheet of transparent plastic and the edges of the sheet are weighed down with stones or other heavy items. In a more costly version there is a black plastic sheet laid over the insulating layer. The edges of the black plastic and translucent plastic are rolled together to give a sealed envelope. The solar heater is retained in the sun for at least 5 hours. After solarisation the grain should be allowed to cool before it is placed in store. If the grain is placed in an insect-proof container (see Secton 7 Table 1 for suggestions when to use solarisation) then it will remain free of infestation. If there is free access to insects then after some while (2-3 months) the grain

may become reinfested. To avoid this the grain should be retreated each month. So if the grain was solarised on the 1st of June, then it should be solarised again on 1st July.

How to solarise cowpea (and potentially other types of grain) to kill insect pests

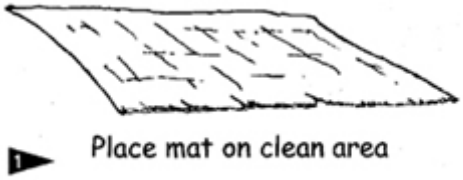


1. Select an open area with no shade, sweep the area to remove any stones or rubbish.



2. Bring up a straw mat (Zana), the mat will be used to prevent heat being lost into the ground

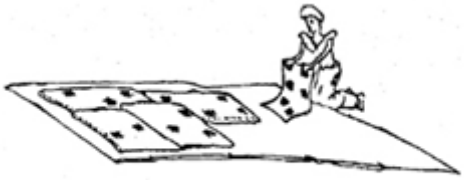
3. Lay the mat out so that it is flat



4. Bring several old jute bags, ideally they have been soaked in boiling water to kill any insect pests. If that is not possible then shake the bags well and make sure they are clean.

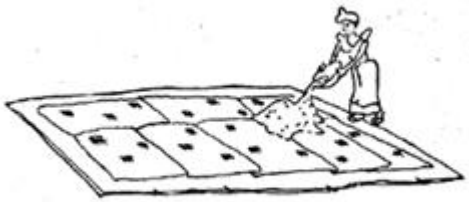
Shake jute bags well

5. Spread the jute bags out on the mat. The bags will stop the beans from spilling over, and help retain heat.



Place jute bags on mat

6. When the bags have been laid out on the mat pour the cowpeas onto them.

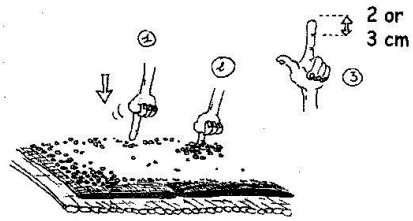


Pour cowpea on jute bags

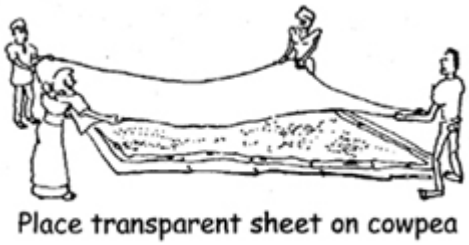
7. Then spread the cowpeas uniformly, the cowpeas should be at the same thickness all over the bags

Spread cowpea evenly

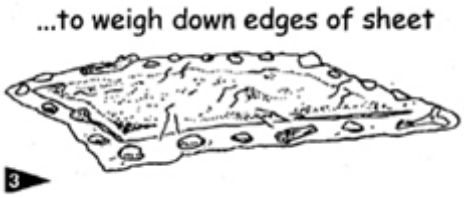
8. Use your finger to check the depth of the cowpea layer. It is best to have a layer only one grain deep but if space is short then it should not be more than about 2 or 3 cm deep anywhere. This is very important , otherwise the temperature will not rise enough to kill all the insects.



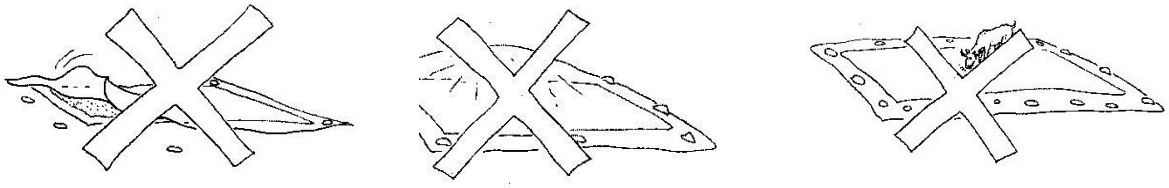
9. Bring the transparent plastic sheet and place it on top of the cowpea layer.



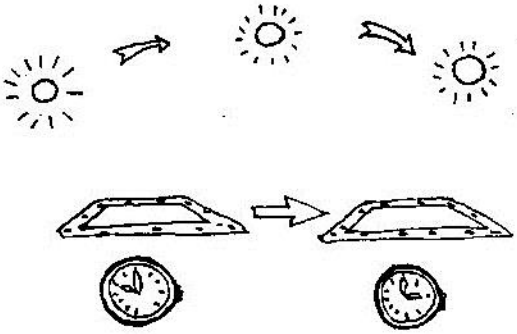
10. Weigh down the edges of the plastic sheet with stones or other heavy items



11. Make sure that a) the plastic sheet is well fixed down, b) there is no space between the cowpea layer and the plastic sheet and c) animals kept away from the area



12. Leave grain in the sun for as long as the sun is hot: from 10 o'clock in the morning to 3 o'clock in the afternoon.



13. If the treatment is interrupted then you should re-do it as soon as possible for the entire period.

14. During the day of solarisation, prepare the store to receive the solarised cowpeas by cleaning the fabric of the store and cleaning bags (Section 1).

15. Allow the cowpea to cool down before placing them in the store.