Protection of Grains and Cereals- A Review

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ABSTRACT

The protection of stored grains against insects was reviewed. The various sources of insect infestation of stored grains and the type of insects infesting grains were identified. It was observed that poor handling of the crop products during harvesting and processing prior to storage among others were identified as sources of insect infestation of stored grains and this result in poor quality and loss in market value of the grains. It was established that susceptibility of the grains to attack by insects was influenced by their moisture content. Hence, long- term storage, grains must be dried to safe moisture content. As preventive measures, good sanitation practice will help farmers reduce pest population. Grains can be sun dried when insect presence is noticed, during sunny weather. Mixing of local plants with grains for example dried neem leaves, dried pepper among others, the use of fumigants and the knowledge of the biology of the insect pests will help to reduce the menace of insects from our stored grains. In order to minimize the problems of insect pests on stored grains, harvesting methods be improved upon as to reduce grain losses due to injury which attract insects. Design of warehouses should be done in such a way that effective storage of grains will be achieved (good site location, proper ventilation etc), stored products chemicals manufacturing company be set up in Nigeria while research institutes and universities in the country be given sufficient fund to execute research programmes on effective crop storage.

Key words: pests; production; good agricultural practice; cost; insecticide.

Introduction

Safe storage of grains and food products against insect damage is a serious concern. It has been estimated that about 9% of the world’s grain production is lost to post harvest insect and mite’s infestations due to unfavourable climatic and storage conditions (Rahman et al; 2009; Tooba et al; 2005). Protecting stored grain and oilseed crops from spoilage is an essential part of their production; failure to do so may result in their being downgraded. Heated or insect- and mite-infested crops in storage quickly lose weight and quality and may cost individual farmers thousands of dollars in lost income. Storing grains and oilseeds cool and dry in clean, uninfested bins that are weatherproof and well-aerated prevents such losses, maintains quality, and assures saleability. The small, light- avoiding insect and mite pests of stored crops can penetrate deep into bulk-stored crops. In empty bins, they hide in cracks and crevices where they survive in residues until a newly harvested crop arrives. Most do not attack field crops and are not brought into storage with the grain, although rice weevils and lesser grain borers infest cereals in the field in warm climates. Stored-product pests also feed on dried animal and vegetable matter and on moulds; some survive on food that contains as little as 8% moisture. Cold-hardy insects can survive the winter in stored crops. During summer, some insects fly and can be carried by the wind from infested grain residues and animal feeds to granaries.
and even into houses. In many cases small improvements in storage methods may already lead to much better protection of stored product and thus to less losses. A good storage building is one thing, good safety measures another. Time honoured methods such as the use of natural materials like plants; minerals and oil are still very effective. Due to the introduction of chemicals many traditional storage treatments are often forgotten. According to a 1990 survey of extension specialists throughout the United States, stored grain losses exceeded $500 million for the year. Most of these losses resulted from infestation by several species of insects and damage by numerous molds and mycotoxins. In most countries grains are among the most important staple foods because these are considered the most important storage products for small-scale farmers in the tropics. However they are produced on a seasonal basis, and in many places there is only one harvest a year, which itself may be subject to failure. This means that in order to feed the world’s population, most of the global production of maize, wheat, rice, sorghum and millet must be held in storage for periods varying from one month up to more than a year. Grain storage therefore occupies a vital place in the economies of developed and developing countries alike. The market for food grains is characterized by fairly stable demand throughout the year, and widely fluctuating supply. Generally speaking people’s consumption of basic foods such as grains does not vary greatly from one season to another or from year to year. The demand for grain is ‘inelastic’, which means that large changes in the market price lead to relatively small changes in the amount of grains which people purchase. Market supply, on the other hand, depends on the harvest of grains which is concentrated within a few months of the year in any one area, and can fluctuate widely from one year to the next depending on climatic conditions. Maize, millet, sorghum, rice and other cereals account for about 70% of the total calorific intake in most African countries (Aworh, 1999). Food grains constitute the major means of meeting the dietary requirements of the Nigerian populace and livestock feeds. Unfortunately their availability to consumers is hampered by losses at various levels in the post – harvest system. Insect infestation of stored grains has been a major problem throughout the world. However, it was reported by several authors that insect pests are about the most important deteriorating agent that reduces cowpea and groundnut quality and quantity in stores in Nigeria. It was estimated that about 37% is lost to pests during the storage of cowpea for a period of nine months (NSPRI Advisory Book, 2000). The F.A.O. (1980) however puts the total production of cowpea in Nigeria to 56,695 tonnes. This gives about 20,977 tons lost to insect. An estimated groundnut production of 676,717 tonnes was declared by the Northern Nigeria Marketing Board in 1964/65 season and with the estimated storage loss of about 8%, 54,143 tonnes might have been lost in 1964/65 season due to improper storage (NSPRI Advisory Book, 2000). Therefore, efforts should be directed to findings methods of protecting our food grains from insect attack during storage in order to meet the competitive needs of livestock and human race.

Sources of insect infesting stored grains
Most of the insects that affect stored grains develop most rapidly at temperature between 25 and 30°C and relative humidity in between 70 and 80%. Insects are introduced into the grain from several sources including the following:– field where the crops were grown, vehicle used in transporting the crop, container used in transporting the grains, packaging methods used during transportation from the field to store, floor, walls and ceiling of the storage structure building, surrounding of the storage site, poor handling of the crop products.

Insects infesting stored grains and the damage caused
Insects infesting grain are classified into three broad groups:

Internal Feeders (Whole Grain Pests)
These type of insect feed on whole grains. Some of them are present at the time the grain is harvested and multiply under a favourable storage condition. They spend almost all their life feeding inside a kernel of grain. A good example of this is maize weevil (Sitophilus zeamais).
External Feeders (Bran Bugs)
These insects feed on the surface of grain kernel or only on broken or milled grain (flour). Examples are confused flour beetle (Tribolium castaneum), red flour beetle (Tribolium confusum), saw-toothed grain beetle (Oryzaephilus surinamensis) and khapra beetle (Trogoderma granarium).

Mould Feeders
These insects are associated with mouldy grains. Example is rusty grains beetle (Cryptolestes ferrugineus).

Stored product pests and their life cycle
Maize weevil (Sitophilus zeamais) (Motschalsky)
Maize weevils are mostly pests in the southern and temperate zones, in fields, of cereal grains mostly, but given a chance, will infest finished products. The adults are accomplished fliers, but cannot normally overwinter, outside, in the temperate zone. They can survive a few hours at freezing temperatures and will survive in heated storage facilities. The females lay their three to four hundred eggs by using their ovipositor to insert one egg into each seed or kernel. Eggs hatch in a few days, and the larvae will eat the inside of their kernel, pupating inside. The entire life cycle takes one to two months, depending on temperature. Their life cycle takes no less than a month or so, and is quite similar to the Rice weevil. Maize weevils are larger and better fliers than the Rice weevils. Larvae develop within the grain and on emergence leaves a characteristic round hole which causes serious losses in weight, sensory and nutritional qualities.

Rice Weevil (Sitophilus oryzae) (Linnaeus)
This is a major pest of rice. It causes serious losses in weight, sensory and nutritional qualities by spending almost all their life feeding inside a kernel of grain. Rice weevils are primarily grain feeders, but will attack almost any kind of whole grain, as well as nuts, beans, and even some fruits. They are strong, accomplished fliers, and will fly from one field to another, infesting grains before the actual harvest. The female bores a hole in the kernel and deposits an egg, and she can lay up to 400 eggs in her lifetime. She seals the egg inside the kernel with a material she excretes, sealing the egg up inside the kernel. The larva hatches within 72 hours, and then starts feeding, within the kernel, and molting four times before pupating. The white, legless larva, with a dark head, are only found within the seeds they are infesting they are not usually seen. The entire life cycle takes only a month or so. It completes development from egg to adult in 28 days at 30°C and 14% moisture content. The adults are about an eighth of an inch long, dull reddish-brown in color, with four red or yellow spots on their wing covers and irregular round pits on their pronotum. The head is an elongated snout.

Granary Weevil (Sitophilus granarius) (Linnaeus)
This insect pest attacks all kinds of grain causing serious damage and contamination to the seed embryo. Development from egg to adult takes 25 to 35 days under optimal conditions of 26 to 30°C and 14% moisture content.

Bean Weevils
Callosobruchus maculatus (Fabricius)
Acanthoscelides obtectus
Caryedon serratus
The most abundant insect species is C. maculatus. C. It could withstand low moisture condition better than other stored product insects because the “active” form of the beetle can transform into “inactive” form. These bean weevils attack all kinds of beans and peas, including cowpeas. C. maculatus has a preference for cowpeas, pigeon peas and lentils and C. serratus prefers ground nuts. The larva feeds inside the beans and, when numerous, may leave nothing but the shell thereby causing serious weight loss, reduction in quality, nutritive value, germinability.

Red Flour or Grain Beetle (Tribolium castaneum) (Herbst)
Cornes (1974), reported that T. castaneum and Trogoderma granarium are the two important pests of groundnut in storage. They severely damage all stored grains including cereal products, nuts,
spices etc. Infestation leads to persistent disagreeable odours of the products. (Odeyemi and Daramola, 2000)

**Saw-Toothed Grain Beetle** *(Oryzaephilus surinamensis) (Linnaeus)*

They are named primarily because of the six sawtooth-like teeth found on the two sides of the first segment behind the head, the pronotum. This is one of the most common insect pests of milled grain, particularly home-stored milled grain (secondary pests of cereals and its products). The adults are small, thin, dark brown insects less than a quarter inch long. They are able to get into packages of flour that are apparently tightly sealed due to their flat shape. The damages here are caused by both the larvae and adult. They are also found on copra, spices, nuts. (Odeyemi and Daramola, 2000). An adult female will lay, over her lifetime, almost 300 shiny white eggs in the food they are infesting. Eggs hatch into tiny, yellow-white larvae, about an eighth of an inch long, and have three pairs of legs and a false pair. A larva will molt as many as four times, and depending on conditions, will complete this cycle in slightly less than a month. If conditions are not ideal, that cycle could take almost a year. In warm grains it takes about 22 days for the egg to adult under optimal conditions of 31 to 34°C and 14 to 15% moisture content.

**Confused Flour Beetle** *(Tribolium confusum) (Jacquelin du Val)*

The confused flour beetle and the red flour beetle look very much alike. Slender, beetle-looking things, they are reddish-brown and about an eighth of an inch long - about the size of a grain of rice. Both are major pests of flour and flour products. Unlike the red flour beetle, the confused flour beetle is more common in flour mills than elsewhere, and the adults do not fly. They cannot penetrate nor feed on whole grains, but can be found in virtually any other processed food product. This includes anything manufactured with flour products, dried fruit, spices, chocolate products and even tobacco products. Adult females will deposit as many as three or four of their sticky white eggs, per day, in the product itself, or in the cracks and crevices of packaging materials. They can produce as many as 400 to 500 eggs in their rather long lifetime. Eggs hatch in about two weeks and the tan colored larvae go through as many as 12 molts, reaching adult stage in about a month. Ideal conditions produce as many as six or seven generations in a year. Any product infested with these pests acquires a rather distinct odor (and flavor) as a result of secretions from their very active scent glands. These two flour beetles are quite common. Most homeowners see this problem happen every once in a while.

**Khapra Beetle** *(Trogodera granarium)*

This insect pest attacks cereals, groundnuts and grains legumes, impairs quality of oil from oil seeds. Larvae may enter a resistant resting phase persisting for several years.

**Grain Moths**

*Ephestia cautella (Walker)*

*Corcyra cephalonica (Olivier)*

*Sitotroga cerealella (Olivier)*

These group of insects’ pest attacks all kinds of grain including sorghum, maize, rice, wheat etc. casing serious damage, weight loss and contamination.

**Lesser Grain Borer** *(Rhyzopertha dominica) (Fabricius)*

This is a major pest of stored grains including sorghum and maize in dryer tropical areas.

**Rusty grain beetle** *(Cryptolestes ferrugineus) (Stephens)*

It usually feeds on the germ (embryo) part of a whole seed. Heavy infestations cause grain to spoil and heat.

**Fungus beetles**

These pests usually infest tough or damp grains and oilseeds and feed on associated dust and moulds. Dry seed bulks stored next to tough or damp seed bulks may also become infested. The foreign grain beetle, the square-nosed fungus beetle, and the sigmoid fungus beetle are the most
common fungus-feeding insects found in stored grain and oilseed crops. Certain species of fungus beetles resemble the rusty grain beetle.

**Hairy spider beetle** (Ptinus villager) (Reitter)

This beetle is mainly a pest of wheat flour and animal feeds but may also infest stored grain near the surface. Adults and larvae have strong jaws, which they use to chew large, irregular holes in the endosperm of kernels. There are several kinds of spider beetles, for example brown spider beetle. The life cycle from egg to adult takes from 3-7 months. Spider beetles have two generations per year and the adults can live for one year (Stromdah et al; 2001). Spider beetles can remain active during cold weather, and can be difficult to control because they also infest such a wide variety of products. The larvae develop on the foods they eat and old storage buildings can harbor infestations in collections of stored products.

**Psocids** (booklice) (Lepinotus reticulates) Enderlein,( Liposcelisbostrychophilus) Badonnel.

‘silverfish’ so called because of its shiny gray appearance, most of us see a silverfish at one time or another. These insects are slightly larger than grain mites. The adult is soft-bodied and about 1.0 mm long. In most years psocid cause no major problems, although they can feed on damaged kernels and are found in tough or damp grain.

**Mites** (Arachnids)

Mites are the smallest of the stored-product pests. They are common in grain stored at 14-17% moisture content but, because of their microscopic size, often go unnoticed.

**Yellow meal worm**

The rather large Yellow meal worm, are shiny black beetles, a half inch long, with well-developed wings, are accomplished fliers and are attracted to light. They are named for the larva, which are more than an inch long, hard-bodied and are bright yellow. Seldom a pest in homes, they are, however, major pests in storage facilities, in dark, undisturbed locations. They feed on these forgotten residues, overwinter in the larval stage and emerge, in the spring, to begin feeding on the food they are infesting. The adults can lay up to 300 eggs and will live about three months.

**Post-harvest grain losses caused by insects**

Insects are the most important organism responsible for damage to stored grain (Aworh, 1999). They cause considerable post-harvest grain losses in several ways including:

- damage to the germ (embryo) of the seed.
- eating other parts of the seeds which also reduce the viability and insect infestation may cause poor seed germination and reduce plant vigour.
- polluting the seeds, which then require cleaning, leading to seed loss.
- increasing the temperature and humidity so that condensation may occur, which enhance the possibility of fungal growth.
- enhancing mouldiness resulting in food losses and poisoning as well as food.
- transmission of diseases.
- quantitative and qualitative losses in excess thirty (30%) per cent insects over a period of one season.
- loss in market value.
- reduction in the storability of grains.

**Suppression of insect population and damage**

Harvested grains usually have a relative high moisture content and as such are too wet for long term storage. Such high moisture grains have high respiration rates and are liable to damage by fungi and insects. Therefore, the susceptibility of grains to attacks by insects is determined by their moisture content hence for long term storage, grains must be dried to a moisture content in equilibrium with a relative humidity of not more than 70% at about 27°C. This optimum moisture content depends on the nature of grain and varies from commodity to commodity (Aworh, 1999).
Methods of controlling insect pests in stored grains

Solar radiation when grains are sun dried, insects already in the grains emigrate as a result of elevated temperature (over 40°C) which is unfavourable to them. However, the eggs and larvae present inside the grain may not be killed. The mixing of the grains with wood ash (or ash of burned rice husks), burned cow dung, fine sand, or certain types of kaoline clay in a volume ratio of ash grain equal to 1:1 to 12, and grain 1:10 will help check insects problem in stored grain (Hall, 1980). Bone ash is also found to be effective as a grain protectant (Nwaubani and Fasoranti, 2008). The effect of kaolin clay is greatly enhanced if sulphuric or hydrochloric acid is added and subsequently heated to 400°C. The materials used, fill the spaces between the grains, thereby restricting insect movement and emergence. A similar method is the admixture of small cereal grains, for example millet, with maize or sorghum. Certain vegetable oil, such as palm oil and groundnut oil applied to pulses, give protection against bruchids.

Plants such as Azadirachtaindica (A. Juss), Cassia fistula (L.), Calotropisprocera (Ait), Lantana camara (L.) and Chrysanthemumcoronarium (L.) have shown insecticidal, antifeedant, repellant and growth regulating properties (Deka and Singh, 2005; Singh and Singh, 2005; Prakash and Rao, 2006; Kestenholz et al., 2007; Neoliya et al., 2007; Sankari and Narayanswamy, 2007). They are traditionally and widely used as stored grain protectants due to their easy accessibility and biodegradable nature. Infrared treatment of rough rice to control stored product insecta rice temperature of 70°C was adequate to control all insects in rough rice, however rice temperatures of 50 and 60°C resulted in reduced insect numbers, but not total control (Siebenmorgen and Derek 2006).

Using pneumatic grain-handling equipment

Most free-living adult and larvae insect pests are killed during bin unloading by using a “grain-vac.” Insects are killed by abrasive contact and impact as the grain and insects are moved through the discharge tube. Better control is achieved when there is a 90° bend in the tube; this causes more contact of insects with the sidewalls of the tube.

Diatomaceous earth

Control of rusty grain beetle can be achieved by using a nontoxic dust made from prehistoric diatoms. When rusty grain beetles come in contact with this dust, the waxy covering on their skin is absorbed, leaving them prone to dehydration and death. The product is applied to grain as it is augered into the bin, and is most effective when applied to dry grain at harvest. Control can take up to five or six weeks. (CRC, 2001)

The use of ozone

This is a new method pioneered by at Purdue University researchers in which they have discovered that ozone can eliminate insects in grain storage facilities without harming food quality or the environment. Ironically, the gas is being touted as a fumigant alternative in response to an international treaty banning the use of ozone-layer harming chemicals currently used to rid food storage facilities of insects. When ozone is used for killing grain insects, it lasts for a very short period of time without damaging the environment or the grain.

Use of smoke

The smoking of the product also help to check insect infestation, the smoke and heat of fire drives insects out of the product to be stored and killed them.

Modified controlled atmosphere

This method involves altering the composition of air and specifically the gas needed oxygen which these insect pests require for survival, reproduction, metabolism, movement and development. The method is based on airtight mode of storage in which the levels of oxygen is reduced from 21% by adding controlled high carbon oxide and nitrogen concentrations (they are inert gases) and they do not react with the stored grains. It is a very good method for long term storage solving also the problems of moisture migration and condensation most especially in the tropics but prohibitively expensive. (Odeyemi and Daramola, 2000)
Biological control

This involves the use of a predator of the insect pest and also manipulating biotic facets of the pests’ life system such as the reproductive processes, its behavior and quality of food. This ensures the equilibrium of the population. It is an environmentally friendly method. (Odeyemi and Daramola, 2000)

Host plant resistant

This involves correlation of plant species resistance with physical characteristics such as long tight husks which reduce attack by weevils and grain moths, importance of integrity of husks such as seeds with gaping or damaged husks which are more susceptible to attack, antibiosis in seeds of some plants which contain chemical substances unacceptable to certain insects, physical and nutritional properties of seeds such as hard seed coat or vitreous endosperm which contributes to resistance, definite oviposition preferences which exists among seed species and varieties. (Odeyemi and Daramola, 2000)

Hermetic Storage

This is the storage of grains under airtight conditions. The dried grains are placed in airtight vessel with some insects usually present by natural infestation and the insects metabolise the starch and sugars of their food to produce carbon dioxide in the presence of oxygen. The ratio of carbon dioxide molecules produced to oxygen consumed is called respiratory quotient and its useful in knowing the level of carbon dioxide and oxygen. In practice, the apparent R.Q., in a filled store is about 0.7 and when the level of oxygen falls to 2% through metabolic activity of the insects, the carbon dioxide level is 15% which will discourage the activity if insect. Unfortunately, it cannot be used in the tropics successfully for high moisture grains due to the fact the grains will have fungi infestations producing toxins thus rendering the grains unsuitable (Odeyemi and Daramola, 2000).

Treating with insecticide

Approved insecticides are selected largely on the basis of the following:

- low toxicity to mammals and high toxicity to insects freedom from taint or odour on food non persistent environmental effects safe, economical and easy use presence of negligible residues or toxic products in food. Some insecticides are more effective and longer lasting than others. Premium-grade malathion, cyfluthrin, pyrethrum with piperonylbutoxide are at present the insecticides registered for empty-bin treatments. Long-term protection of stored cereal can be achieved by adding premium malathion or diatomaceous earth. As insecticide sprays and dusts act only on contact with insects and do not penetrate piles of grain or dust on floors, residues from the granary should be removed before applying the insecticide. In cold weather, oil solutions of insecticides are better than water-based sprays because they will not freeze. Oil solutions can be prepared by mixing insecticide in deodorized kerosene following label instructions and can be used near electrical switches. Wood or metal surfaces can be sprayed and empty bins fogged, but avoid treating plastic or rubber surfaces with oil solutions. Insects beneath the floor or within wall spaces may be controlled with insecticide powders or dusts, because these places are hard to treat with liquid insecticides. These powders or dusts are usually commercial formulations of malathion on treated wheat flour. Use a dust applicator or sweep the dust into cracks in the floor. Oilseeds absorb contact insecticides from treated granary surfaces. Therefore, avoid treating granaries in which oilseeds are to be stored. If the granary is infested, sweep it well, destroy the sweepings, and treat sparingly only the junctions of the floor and walls. If stored-product insects are visible on the outside wall of the granary, spray the walls and surrounding ground. Even if insects are not readily visible, it is a sound practice to spray not only grain spillage, but also the ground around the granary and underneath raised granaries. (CRC, 2001)

Grain treatment

Grain treatment is not a substitute for good housekeeping; however, special formulations of premium-grade malathion are available for treating cereals for long-term (8 months to 1 year) protection from insects. Either liquid insecticide is sprayed on the grain, or dust composed of treated wheat flour is mixed with the grain at rates that are dependent on its flow through the auger. To treat the grain with a 1% spray of premium-grade malathion, apply it at 0.8 L/t of wheat. Use Table 5 to determine the amount and rate of malathion for application. The treatment is effective as a protectant,
but the grain should be stored in good condition and contain less than 14% moisture, otherwise the insecticide will break down quickly, reducing its residual activity.

### Table 1. Amount and rate of premium-grade malathion required for application

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<tr>
<th>Flow rate (wheat)</th>
<th>Application rate (1% spray)</th>
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<tr>
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<td>15</td>
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(CRC, 2001)

### Fumigation

Fumigants generate toxic gases that are used to control insects in stored grain. They are available for farm use only as solid formulations. Fumigants are also toxic to humans and farm animals and, therefore, must be applied only by trained people. The vapour should not be inhaled, and the directions on the container must be followed. CO₂ is registered for fumigation of grain, but bins must be made airtight; welded steel hopper bins can be made airtight for about $300.00 and the cost of fumigation with dry ice (CO₂) is comparable to phosphine treatment, only slower. The solid fumigant aluminum phosphide, which generates phosphine gas in the presence of air moisture, should be applied only when the following conditions are met:

- Licensed personnel must apply fumigants. For example Nigerian Stored Products Research Institute, Agricultural Extension Services Produce Inspection Services, Pest Control Association of Nigerian members or certified commercial pest control operators.
- The grain temperature is at least 10°C. Fumigants are most effective at temperatures higher than 20°C. If the grain is below 5°C, fumigation should not be done.
- The grain must be cooled to decrease the severity of the infestation by moving it to another bin or by aerating.
- Full-face gas masks in good condition and with the appropriate canister for phosphine, cotton gloves and protective clothing must be available to wear during application.
- The infested grain is stored in a granary that can be tightly sealed to retain the gas for at least 5 days by plugging cracks, crevices and other openings. In calculating fumigant dosage on the basis of bin volume, include the headspace above the grain. Correct number of tablets or pellets as recommended by the manufacture must be used. Tablets or pellets of solid fumigant (aluminum or magnesium phosphide) is added either to the grain stream as it is discharged from an auger into a sealed bin or by probing them into the grain at regular intervals once the bin is filled. Small bins of about 27-tonne capacity are treated by dropping the fumigant through metal pipes inserted into the grain. Selection of about 12 evenly spaced points on the surface of the grain is done and mark with wooden stakes. Insertion of a pipe 3-cm in diameter and 1.5 m long at each point to be followed by the dropping of a tablet into the grain every 15 cm as the pipe is withdrawn. Start at the far end of the bin and work towards the door and put some tablets into the auger hole before sealing. (CRC, 2001). In bins that cannot be tightly sealed at the top, the grain would be covered with polyethylene sheeting to reduce loss of fumigant and to improve effectiveness of treatment. It should be noted that insecticides such as pyrethrum, synthetic pyrethroids, actellic and malathion that are safe for use on stored grains may be applied as a spray or dust (powder).

### Outcome of Review

This review showed that insect pests constitute a great problem in storage of grains. It was also revealed that knowledge of the biology of insect pests will facilitate their control. Premature drying of the crop before maturity results in shrinkage of grains during storage. The problem of poor storage structures, improper handling during harvesting and processing of food grains are the major causes of losses. There is the problem of inadequate inspection of produce. The methods of transporting food grains from the farm to the store expose them to mechanical injuries thereby creating room for infestation of the grains. The re-absorption of moisture from humid air during storage through the use of inappropriately designed and crack storage material causes deterioration of the stored grains thereby reducing the quality and the market value of the grains. A good
management of stored grains through the combination of both preventive and control measures such as proper handling of the food grains during harvesting and processing, provision of good storage structures, regular inspection of food, grains stores and fumigation of warehouses will minimize the losses of food grains to insect pests. Having looked at the problems of insect pests on stored grains in its entire ramification, it is therefore, clear that grains losses to insect pests is a product of many variables, some of which are interwoven. Example of this could be seen from S. zeamais which has the gradient of infestation from the field to the store. Therefore, losses due to it are difficult to assess precisely because of the stages involved.

**Recommendations**

Good storage and sanitation practices will help farmers reduce pest population on their farms and in store houses. To keep infestations from spreading to other granaries, pests should be controlled as soon as they are discovered. The type of control implemented will depend on the condition of the grain, bulk temperature, kinds of insects or mites present, and the time of year In this regard, the following precautions should be taken before bringing new crop into the grain store: Do not mix old grain with new grain.

**Remove all damaged and infested grains**

Cleaning the grain also checks infestations. To control surface infestation of moths, mites and spider beetles, remove and destroy webbed and infested patches, rake the bulk surface to break up any crust, and then dry the bulk. Prepare the grain store or grain bin before storing the new crop: sweep or vacuum the floor and walls; burn or bury sweepings that contain spoiled or infested grain; seal cracks to keep out rain, snow and flying insects; and spray the walls and floors with a recommended contact insecticide.

Install an aeration system to reduce grain temperatures and to reduce moisture migration.

**Dry tough or damp crops soon after harvest because they are more likely to become mouldy or infested with insects and mites than dry (straight-grade) crops; then cool after drying.**

Examine stored crops every 2 weeks for signs of heating or infestation; check either temperatures or carbon dioxide levels; and check insect activity by using traps, or probe and sift grain samples.

Heated or mouldy crops should be dried. If the heated grain cannot be dried immediately, the rate of deterioration can be reduced by cooling the grain by aeration or moving and mixing the spoiling grain with cooler grain.

Insect infestations can be controlled or eliminated by cooling the grain by aeration or mixing it with colder grain.

**Observe safety precautions when applying insecticides; only persons licenced for fumigation application should apply fumigants.**

Make sure that you clean the grain store thoroughly, remove all spilled grains, logs etc. and dust all grain handling equipment, disinfest sacks, baskets, utensils etc. by chemical treatment or by exposing them to the sun.

Bagged grains should be dried to between 12-13% moisture content before being taken to store. Stacks of bags should be placed on wooden pallets. This will prevent moisture absorption by the bagged produce and mould damage.

**Cooling and cleaning the product. An effective method to control insect infestations in winter is to lower the grain temperature. This can be done by mixing and transferring infested crops from one granary to another which will lower grain temperatures about 10°C in the winter; or by transferring part of the crop to a truck or small pile exposed to low air temperature, leaving it to cool for one or more days and then returning it to the granary.**

However, aeration systems are much more effective at lowering the grain temperature. Insects do not develop or feed at temperatures below 10°C. At temperatures below 0°C, the insects will die eventually. Control of the rusty grain beetle will be obtained:

- after 1 week at a grain temperature of -20°C
- after 4 weeks at a grain temperature of -15°C
- after 8 weeks at a grain temperature of -10°C
- after 12 weeks at a grain temperature of -5°C
Because the rusty grain beetle is the species most resistant to low temperature, most other insects in stored grains and oilseeds will also be controlled by these combinations of temperature and exposure periods. The low temperatures listed here do not kill fungi or all mites.

Storage warehouse

Since one of the most efficient methods used for storing grains on a large scale is by bagging dried grains and storing them in properly designed warehouses, must have the following features:

- It must be weatherproof; the roof, walls and other parts of the building must be leak proof, and the floor must not transmit water from the soil.
- It must be rodent and bird proof. Metal guards and wire netting should be used.
- It should be possible to seal the entire warehouse completely to allow fumigation.
- It should be designed and built to allow controllable ventilation.
- It must prevent moisture from the floor from reaching the bagged grains by putting the first layer of bags not directly on the floor but rather on a plank, plastic sheet, thick mat etc.
- Mechanical harvest should only be used where hand harvesting proved uneconomical so as to reduce grain losses due to injury which will expose it to insect pests. Keeping the storage environment clean can help prevent insect infestation.
- Department of post-harvest technology should be established in all faculties of agriculture of Nigerian universities. This will ensure the availability of trained manpower to conduct effective research on storage of grains.
- Food grain stores in standard markets to be built to specifications such as would permit the application of effective storage and protection against insect pests attack.
- Stored products chemical manufacturing company to be set up in Nigeria, to produce chemical, which will satisfy and cope with the needs of the country.
- More use to be made of local crop storage experts rather than foreign experts and consultants. More often than not, these foreign experts are not experts in our problems.
- The Nigerian Stored Products Research Institute (NSPRI) should be given sufficient funds to execute its research programmes on effective crop storage in Nigeria.
- The Extension Service Department of the Ministry of Agriculture through Nigerian Stored Products Research Institute should disseminate recent information on how best to store grains to farmers.

References


Nigerian Stored Products Research Institute (NSPRI) Advisory Booklet (2000). Control of Field to stored pests of maize ears


Prakash RA.2006. Exploitation of newer botanicals as rice grain protectants against Anonmois grain moth Sitotrogachelalaoliv. Entomon -Trivandrum, 31: 1–8


Sankaram SN, Narayanswamy P.2007. Bioefficacy of flyash-based Siebenmorgen TJ, Derek S. 2006. Infrared heat eliminates pests from stored rice Seed Quest Newsletter Fayetteville, University of Arkansas


The predator Xylocorisflavipes to three stored product insect pests. Int. J. Agric. Biol., 11: 316–320