International Institute of Tropical Agriculture
International Maize and Wheat Improvement Center

Insect pests of maize in storage: biology and control

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Research Guide 32

IITA/CIMMYT Research Guide 32

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Insect pests of maize in storage: biology and control

Objectives. This guide is intended to enable you to:

- discuss the importance of insect pests of maize in storage
- describe biology and damage of primary pests and pests of secondary importance
- explain factors affecting preharvest infestation
- explain factors affecting postharvest infestation
- control pests

Study materials

- Reference collection of main pest species.
- Slides of insect pests and damaged grains.
- Samples of damaged grains.

Practicals

- Identify main species of pests.
- Examine grains damaged by different species of storage pests.
- Label specimens.
- Discuss and demonstrate control measures.

Questions

1 Describe the damage on maize in storage in your area resulting from insect pests.
2 What are the ecological elements in the storage environment that affect insect behavior/biology?
3 Why is it important to identify the main pests at a particular locality?
4 What are the life requirements of stored-grain insects?
5 How can you identify storage insects that are small and difficult to identify?
6 How should insect specimens be prepared before sending to a specialist for identification?
7 Give the scientific names and families of two major stored grain insects in your area.
8 How is the biology of these species related to the maize storage forms used by farmers?
9 What are the crops attacked by maize and rice weevils?
10 Why is *Prostephanus truncatus* important?
11 How long is the resting phase of Khapra larvae?
12 When do many of the major pests of stored maize actually infest?
13 What factors influence preharvest infestation?
14 What factors influence postharvest infestation?
15 What are the improvements needed to reduce pest damage?
16 Discuss the effect of grain moisture content.
17 What types of losses do insects cause?
18 Name sources of infestation.
19 Name four major types of control measures.
20 Give examples of means to control storage pests of maize.
21 Discuss the possibilities for integrated control of the larger grain borer.

Insect pests of maize in storage: biology and control

Abstract. Damage and losses to stored maize in Africa are often severe. Storage pests of an area have to be identified to determine whether they merit control and to choose appropriate control methods. Knowledge of the biology of pests and of factors influencing preharvest and postharvest infestation is important to control insect pests in maize storage.

1 Importance of insect pests in maize storage

Insects are a major cause of maize storage losses in the tropics. They infest and damage grain, resulting in direct and indirect losses of both quality and quantity of the food stored. Losses vary according to region, environmental conditions, main storage pest(s) and method of storage. Under certain conditions, weight losses of over 30% have been observed after only a few months of maize storage in some African countries.

The insect community associated with stored maize includes primary pests as well as scavengers, predators and parasites. Each species exhibits different behavior, tolerance of environmental factors, and preference depending on:

- maize variety stored
- form of storage (ear, cob, grain)
- moisture content and temperature
- state of produce (damaged, intact)

Thus, for a particular locality, only a few species are important pests. It is essential to identify the main pests to:

- determine whether an insect can cause serious damage and therefore merits control
- choose appropriate control techniques

Application of knowledge on pest biology in selecting control measures greatly increases the effectiveness of measures.

Practical aspects of pest biology are:

- source of infestation
- resistant or dormant phase

- ability to reinfest
- tolerance of environmental conditions, etc.

Concerning life cycle, most stored-grain insects exhibit complete metamorphosis of which the stages are:

- egg
- larva - not similar to the adult, often "worm-like"
- pupa - "quiet" stage when larva transforms to adult
- adult - reproductive stage

The life requirements of stored-grain insects like any organism are:

- food
- oxygen
- water
- suitable temperature
- protection from environmental hazards
- reproduction for population survival

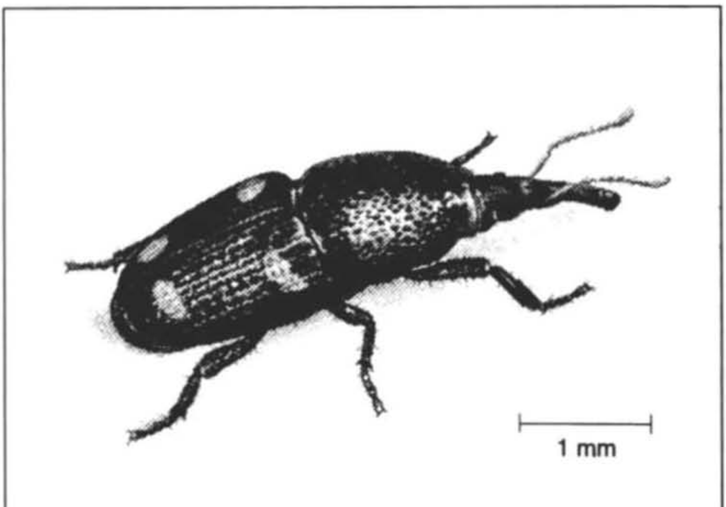
Control measures search for removal of any of the above life requirements.

The majority of storage insects are small and difficult to identify for nonspecialists. The most common pests in an area should be collected and sent for specialist identification. Larvae, caterpillars and pupae should be preserved in 70% ethyl alcohol. Adults should be submitted as found. Specimens should be labelled with locality reference, date and produce concerned.

Maize and rice weevils. *Sitophilus zeamais* and *S. oryzae* (Coleoptera: Curculionidae) (Figures 1 and 2). Maize and rice weevils are distinguishable from all other common storage pests by their long beak or rostrum. *Sitophilus* weevils are the most important pests of stored maize. They are found in all warm and tropical parts of the world and are responsible for heavy losses every year.

Adults are long-lived (up to a year), and females lay eggs throughout most of their adult life. Each female can lay up to 150 eggs. Eggs are laid individually in small holes chewed into the kernel by the female. Eggs hatch in 6 days, and larvae feed inside the grain for approximately 25 days. Pupation occurs inside the grain, and the adult chews its way out of the kernel leaving a characteristic emergence hole.

Figure 1. *Sitophilus zeamais.*

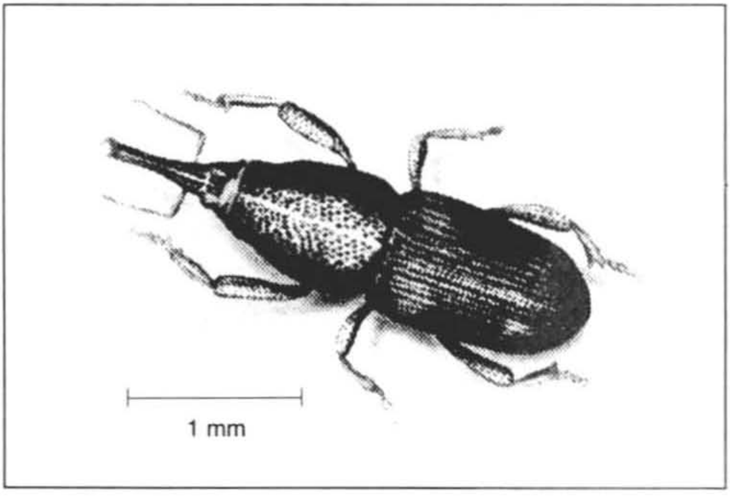


Adult weevils are reddish-brown to black with four reddish-orange circular markings on the wings. Separation of the two species requires examination of the genitalia.

Total development periods range from 35 to 110 days depending on humidity, temperature conditions and host. Under optimum conditions (25–27°C and 70% relative humidity - rh) development requires 30–40 days. Commodities attacked include maize, rice, sorghum and wheat.

Lesser grain borer. *Rhizopertha dominica* (Coleoptera: Bostrychidae) (Figure 3). The adult beetle is 2–3 mm long and has a cylindrical body with the head covered by a hood-shaped pronotum and the anterior margin with distinct tubercles. Females lay eggs outside kernels. Eggs hatch and larvae tunnel the grains.

Figure 2. *Sitophilus oryzae.*



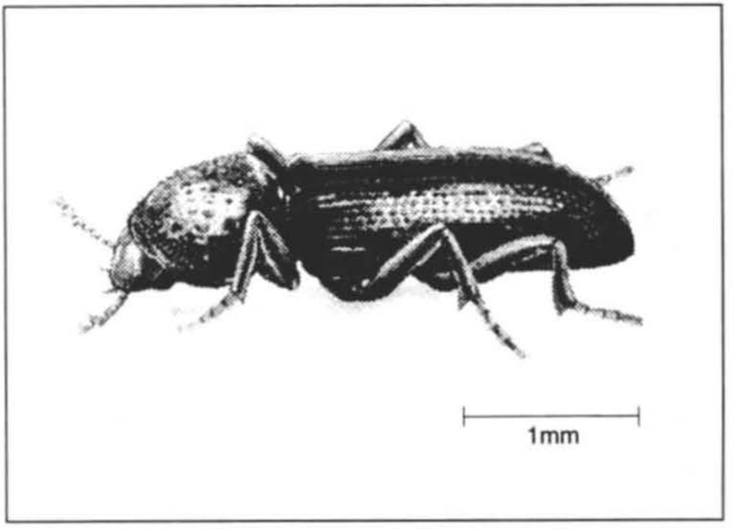
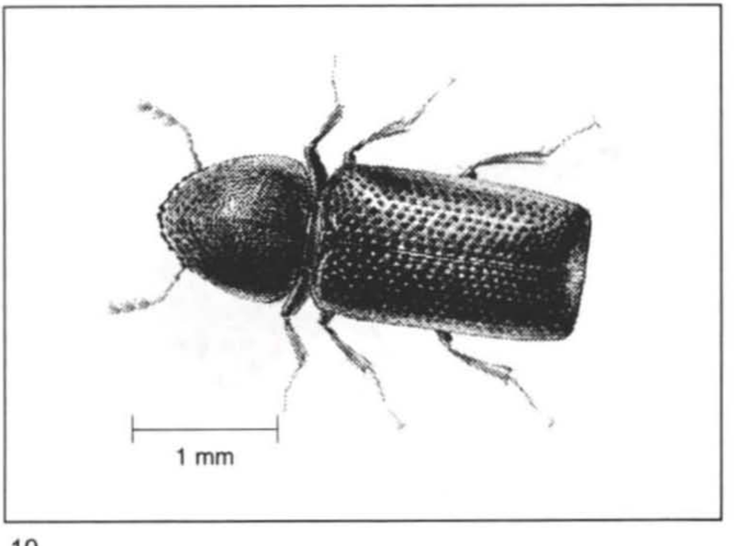


Figure 3. Lesser grain borer *(Rhizopertha dominica)*.

Figure 4. Larger grain borer *(Prostephanus truncatus)*.



Development occurs inside the grain. Under optimum conditions, 30 days are needed from egg to adult. Commodities attacked include sorghum, maize, rice, wheat and dried roots and tubers.

Larger grain borer. *Prostephanus truncatus* (Coleoptera: Bostrychidae) (LGB) (Figure 4). The LGB is similar, but slightly larger (3–4 mm) than the lesser grain borer. It is cylindrical and dark brown in color. The ends of the wing covers are flattened and steeply inclined. The presence of two curved ridges at the tips of the wing covers distinguish LGB from other bostrichid beetles.

Under optimum conditions (32°C, 70–80% rh), the minimum developmental period is about 25 days. This pest is more adaptable to diverse environmental conditions than other storage pests.

The LGB is a serious pest of maize native to the Americas and was recently introduced to Africa. It was first found in Tanzania from where it spread to other East African countries.

More recently, it was accidentally introduced to Togo from where it moved into Benin and Ghana. According to experts, LGB has the potential to spread to all major maize-producing regions of Africa.

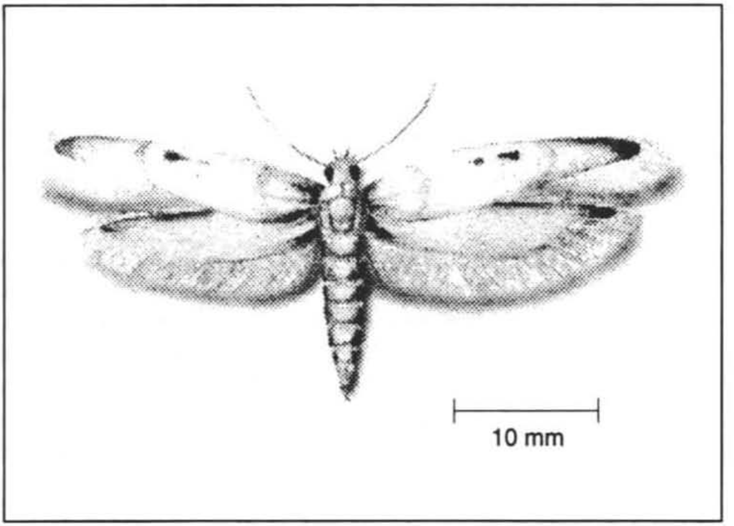
Eggs are laid within maize grains in tunnels created by the adults. LGB adults feed on maize grains on the cob both before and after harvest. Larvae also feed on grain. Damage is severe and losses of maize stored in cribs is as high as 34% after 3–6 months storage (3–5 times higher than losses caused by other pests). Grain dust is produced by the adults as they feed. Adults also feed on wooden structures and dry cassava.

Members of the family Bostrychidae may also sometimes be found attacking the timber of storage structures.

Angoumois grain moth. *Sitotroga cerealella* (Lepidoptera: Gelechiidae) (Figure 5). The adult moth is 5-8 mm long, cream or fawn colored with 1 or 2 small black spots on the forewings. Wings are very narrow and fringed with long hairs. The sharply pointed tip of the hindwing is characteristic. The adult moths live for 7–14 days and mate soon after emergence.

Eggs are placed in clusters among kernels. Eggs hatch and larvae chew into the kernels completing their development to adult within the kernels. At 30°C and 80% rh, development from egg to adult takes about 30 days.

Figure 5. Angoumois grain moth *(Sitotroga cerealella).*



Sitotroga replaces *Sitophilus* as the main pest of stored maize in the more arid areas. Damage may be serious in maize stored on the cob. The adult moths cannot penetrate grain that has been densely packed. Infestation of shelled grain is thus limited to the external layers. Shelled grain suffers less damage than maize on the cob. Sorghum, rice, and wheat are also attacked by the larvae.

3 Storage pests of secondary importance

Moths. *Ephestia* spp., *Plodia interpunctella, Corcyra cephalonica* (Lepidoptera: Pyralidae). All species have broader wings than *Sitotroga* and a shorter fringe of bristles. In some cases, they can be major pests and are important on flour and other products.

Ephestia spp. have dark forewings with sometimes two pale bands (Figures 6 and 7). Females lay most eggs within 3–4 days after emergence since adults live only for a few days. Development from egg-laying to adult averages 35–40 days under optimum conditions. Larvae consume germs of cereal grains. They are serious pests in seed and food warehouses, mills and other processing units.

Plodia has forewings colored cream at the base and red-brown on the outer half (Figure 8). Commodities attacked and pest status are similar to those of *Ephestia* spp.

Corcyra is uniformly dark grey-brown. Webbing is more dense and tough than that produced by larvae of *Ephestia* and *Plodia*. The food material becomes tightly matted together with webbing, larval galleries, cocoons, and frass.

Flour beetle. *Tribolium* spp. (Coleoptera: Tenebrionidae) (Figure 9). Adults are reddish-brown and very active. Females lay their eggs outside kernels and development from egg to adult takes 30–35 days under optimum conditions. Larvae and adults prefer to feed on the germ of the grain. Infestation is usually more serious on damaged grains or milled products.

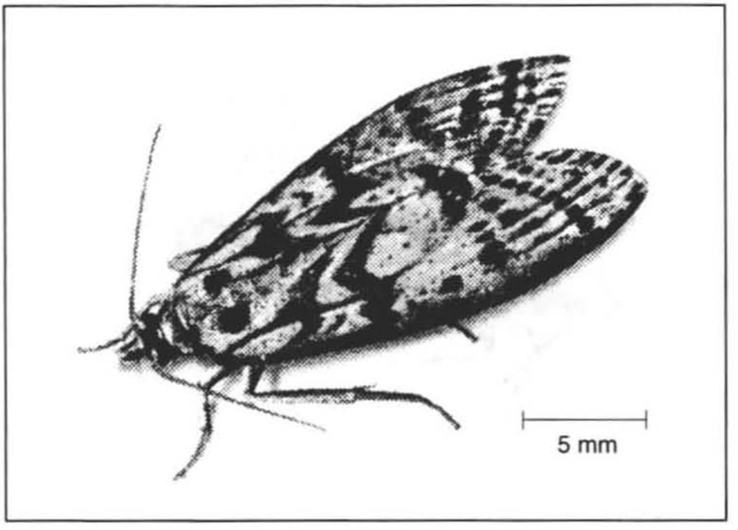
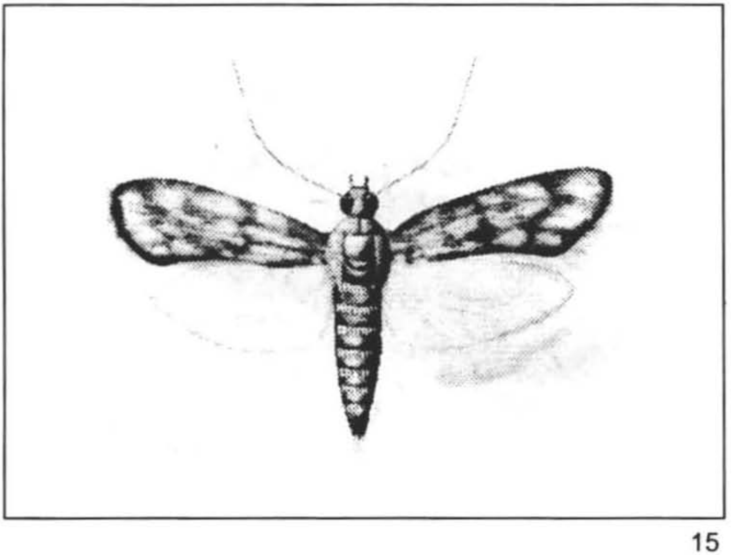


Figure 6. *Ephestia kuehniella.*

Figure 7. *Ephestia elutella.*



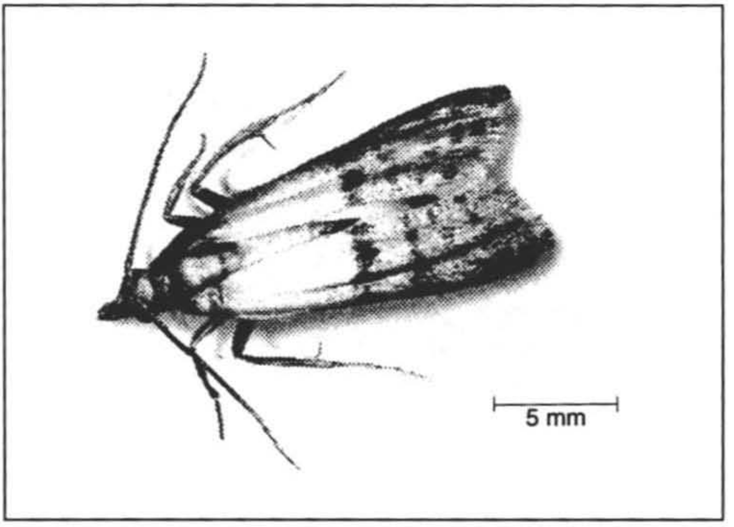
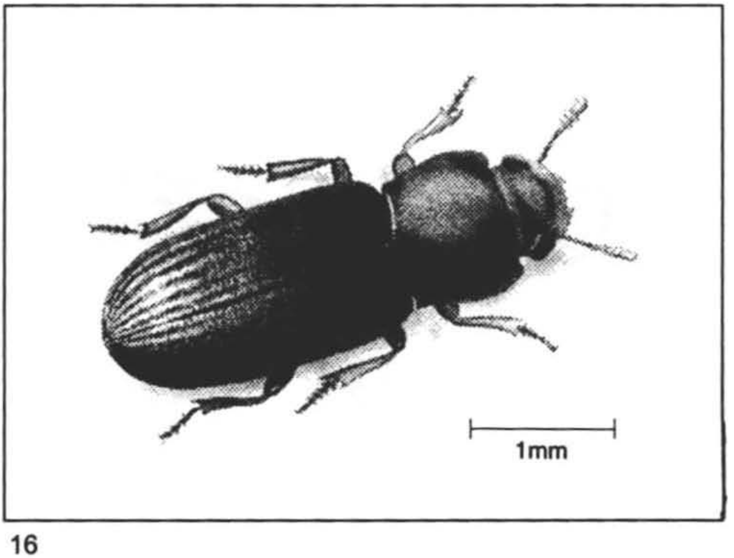


Figure 8. *Plodia interpunctella.*

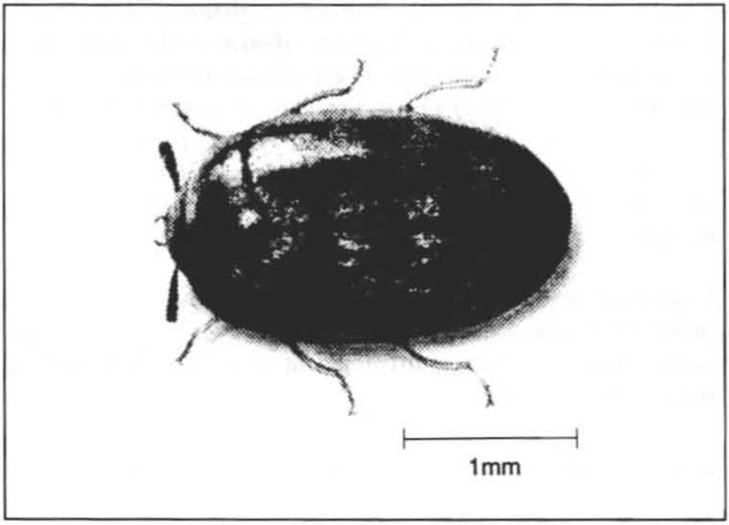
Figure 9. Flour beetles *(Tribolium castaneum).*



Khapra beetle. *Trogoderma granarium* (Coleoptera: Dermestidae) (Figure 10). Adults are small, oval, dark-brown with lighter bands. Elytra are covered with fine hairs. On the larva, segments appear as "rings" around the body. Development from egg to adult may be as short as 25 days. Larvae feed on cereal grains, oil seeds and their products, but also on dry materials of animal origin.

Khapra beetles are major pests in dry areas. They are important partly because larvae can enter a resting phase lasting up to several years. If an infestation is suspected, identification by an expert should be sought.

Figure 10. Khapra beetle (*Trogoderma granarium*).



4 Factors affecting preharvest infestation

Many of the major pests of stored maize infest maize in the field. *Sitophilus zeamais*, *Prostephanus truncatus*, and *Sitotroga cerealella* can all infest maize before harvest, but the minor pests *Rhyzopertha dominica* and *Dinoderus* spp. seem to be of little importance in the field.

Some of the factors influencing preharvest infestation of maize are:

- maturity of maize grain
- husk cover
- location and condition of grain stores
- time of harvest

Maturity of maize grain. *Sitophilus* weevils appear to infest grain only after the moisture content has dropped to a certain level (most likely around 30%). Chemical compounds produced only by mature grains have been suggested to attract weevils.

Husk cover. Both the length and tightness of the husk leaves around the ear will affect infestation by weevils. A tight, long husk cover has been shown to reduce weevil penetration and thus grain damage. Damage to the husk and silks by lepidopterous pests such as *Eldana saccharina*, *Mussidia nigrivenella*, and *Heliothis armigera* and by birds will increase the chances of damage by storage pests.

Location and condition of grain stores. Proximity of infested maize stores to the crop in the field has been suggested as a factor influencing weevil infestation of maize before harvest.

It seems that infested stores are the main source of *Sitophilus* and, thus, the dispersal behavior of this pest is one of the most important factors determining pre-harvest infestation of maize.

Time of harvest. There are conflicting reports on the effect of harvesting date on weevil infestation, i.e., in some cases, infestations appear to be lower as a result of delayed harvest, in others they appear to increase.

Many factors affect farmers' decision to harvest, includeing weather conditions and cash and labor constraints. In the humid forest zone, maize left standing in the field during the rainy season will take considerable time to dry and will suffer increased damage by insects, birds, and rodents. Storing maize at a high moisture content, however, will also result in rapid deterioration as a result of mold growth and insect attack.

5 Factors affecting postharvest infestation

Several factors influence postharvest infestation of maize:

- storage form
- temperature and humidity
- grain moisture content
- condition of the storage place
- type of store
- infestation before harvest

Storage form (shelled grain, husked or dehusked ears). Shelled grain suffers less damage by pests like *Prostephanus* than maize stored on the cob. The opposite is true, however, for *Sitophilus*, *Tribolium* sp. and *Rhyzopertha dominica*. Shelled grain will result in faster population increase of weevils than maize stored on the cob with husks on.

Temperature and humidity. High temperatures (26-30°C) and humidity (70–80% rh) are optimum conditions for the development of storage pests such as *Prostephanus* and *Sitophilus*.

Grain moisture content. Maize stored at high moisture levels (i.e., 30–35%) deteriorates rapidly. Moisture levels of 12–14% are considered safe for storage where *Sitophilus* weevils are the main pests. Farmers use many methods to dry their maize, including spreading it for sundrying, hanging it above the kitchen fire, smoking the crib, making shocks of maize in the field, etc. These methods have different effects on insect populations. *Prostephanus truncatus* is tolerant of hot, dry environments and can survive on maize with moisture content as low as 10%.

Condition of the storage place. Dirty, infested stores result in grain brought from the field becoming rapidly infested with the storage pests surviving in the store.

Type of store. Cribs that do not allow the maize to dry quickly result in an environment that enhances insect activities and thus damage. Cribs should be designed in order to take advantage of air movement which speeds up grain drying and thus reduces insect population build-up.

Infestation before harvest. Insect populations initially develop much faster in maize with higher levels of preharvest infestation than in maize with low field infestation levels. However, this difference becomes less apparent as storage periods become longer.

6 Control measures

Damage and losses to stored maize from insect attack may be as great as those sustained by growing crops. Damage to crops in the field is usually apparent; damage to stored grain may not be apparent.

Insect activities in stored maize may cause various types of losses:

- weight loss
- loss in quality/market value
- promotion of mold development
- reduced germination in seed material
- reduced nutritional value, etc.

Preventing infestation is always preferable to controlling an infestation that has assumed serious proportions. Potential sources of infestation have to be considered.

Pests can survive from the previous season in a variety of forms such as:

- infested residues
- structure of store itself
- natural habitats

Pests can infest fresh maize from:

- active migration into the crop at maturing or at drying stage in the field
- contamination when material is placed in a store already infested
- cross infestation between stored grain

Four major types of control measures are applicable to maize storage:

- inspection
- housekeeping/sanitation
- physical and mechanical methods
- chemical methods

The role of biological control agents and moderately resistant varieties also need to be taken into account.

The most important and effective means of preventive pest control is good housekeeping which, fitted in an integrated pest management program, is of optimal efficiency.

The following are a few examples of control methods for:

- weevils
- larger grain borer

Weevils. Infestation normally starts in the field. Early harvesting reduces infestation. A tight long husk cover will also reduce. The storage place should be free of weevils. Storing maize on the cob with husks on reduces weevil infestation. Low moisture content (10% or less) and low temperatures (below 15°C) prevent weevil development.

Prior to storage, maize can be treated with Actellic 25 EC (20% solution) by spraying the insecticide with a spraygun. There is wide genetic diversity in maize in relation to susceptibility to weevil attack, and it is possible to develop varieties with some degree of resistance to weevils.

Larger grain borer. The optimum strategy for the control of the LGB varies according to location/situation and has not yet been fully established. Hygiene of the storage place/containers is essential.

Although the current recommendation is to shell the maize and treat with an admixture of pyrethroid insecticides, we recognize this is not practical under many situations (i.e., unavailability of insecticides or cash to purchase them, farmers' reluctance to shell the grain due to labor constraints or in order to reduce weevil damage).

The following insecticides are recommended (g/100 kg maize grain):

Permethrin	0.5% dust	-	55 g
Deltamethrin	0.2% dust	-	50 g
Fenvalerate	1.0% dust	-	50 g

Since the LGB is an introduced pest, there is potential for biological control. A predatory beetle, *Teretriosoma* sp., has been identified as a natural enemy of LGB and has been released in some African countries.

The use of imported insecticides for the control of LGB is not practical or desirable in Africa. There is a need to develop an integrated pest management strategy which aims at the control not only of LGB but of the full spectrum of insect pests of maize in storage.

However, before various control methods can be integrated, more information is needed on the importance and dynamics of the various storage pests in the diverse ecosystems where maize is grown and stored in Africa.

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If you use this Research Guide in training...

Generally:

- Distribute handouts (including this Research Guide) to trainees one or several days before your presentation, or distribute them at the end of the presentation.
- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listen to you.
- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (and this Research Guide) contain all relevant information.
- Keep your training activities practical. Reduce theory to the minimum that is necessary to understand the practical exercises.
- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, etc.). Allow consultation of handouts and books during examinations.
- Promote interaction of trainees. Allow questions, but do not deviate from the subject.
- Respect the time allotted.

Specifically:

- Discuss with trainees about experiences and problems with insect pests of maize in storage (10 minutes).
- Present and discuss the content of this Research Guide, considering the study materials listed on page 3 (1½ hours).
- Have real samples of infected maize cobs and grains available for each trainee.
- You may photocopy the illustrations of the Research Guide on transparencies for projection with an overhead projector.
- Conduct the practicals suggested on page 3 in groups (3-4 trainees per group; 2 hours). Make sure that each trainee has the opportunity to practice. Have resource persons available for each group and practical.
- Visit farmers' fields and stores, evaluate damage, discuss with farmers (men and women), and demonstrate prevention and control measures (½ day). After the visit, discuss with trainees about their experiences (1 hour).

International Institute of Tropical Agriculture
International Maize and Wheat Improvement Center

The International Institute of Tropical Agriculture (IITA) and the International Maize and Wheat Improvement Center (CIMMYT) are two of sixteen institutions supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Program (UNDP). The CGIAR is an informal association of 50 donor countries, international and regional organizations, and private foundations.

IITA seeks to increase agricultural production in a sustainable way, in order to improve the nutritional status and well-being of people in sub-Saharan Africa. To achieve this goal, IITA conducts research and training, provides information, collects and exchanges germplasm, and encourages transfer of technology, in partnership with African national agricultural research and development programs.

CIMMYT is engaged in a worldwide research program for maize, wheat, and triticale. The mission of CIMMYT's maize program is to help the poor in developing countries by increasing the productivity of resources committed to maize while protecting natural resources. This will be accomplished through the preservation, improvement, and dissemination of genetic resources; the development of environmentally compatible crop management practices; the provision of research methodologies, and through training and cosulting.

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