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Distinguishing and Controlling Insect Pests of Stored Foods for Improving Quality and Safety

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Abstract

Provision of healthy food has always been a challenge facing by mankind. It has been estimated that between one quarter and one third of the world's grain crops are lost each year during storage and much of this is due to insects attack. In addition, grain which is not lost is severely reduced in quality and quantity by insect's damage. Many grain pests preferentially eat out grain embryos, thereby reducing the protein content of food grain and lowering the percentage of seeds to germinate. In the present article identification of stored food grain insect pests species and various controlling methods are discussed in detail along with emphasis made on the use of non-chemical control procedures. Stored grain insects are divided into primary pests that attack whole kernels, and secondary pests that feed on broken or cracked grain. Some important stored grain pests include the lesser grain borer, rice weevil and rust red flour beetle. The stored food insects often cause as much loss after harvest as crop pests cause during the growing season and profits from producing a crop should not be allowed to waste away in storage. Insect pests also increase costs to grain growers both directly through the expenses of control on the farm, and indirectly through the costs incurred by grain handling authorities in pests controlling within bulk storages. For food store insect's management, prevention, detection and elimination are the steps to pest management needs. The further steps to prevent and control of insects damage are, keep bins clean and repaired, use residual sprays, store only clean and dry grain, aerate the grain, protect the grain, and inspect the grain regularly. Other, common ways to pests control are use of oldest products before newer ones and opened packages before unopened ones. Inspect packages or bulk products before buying and choose packages that are sealed and unbroken. Also check the freshness, packaging date and look for evidence of insects, including holes in the packaging or wrapping, and store insect-free foods in tightly closed glass, metal, or heavy plastic containers.

Keywords

Food Damage, Population Density, Storage Pest, Weight Loss

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1. Introduction

Mostly, the producers, commercial millers and traders store their grain for three purposes; for consumption until the next harvest, as seed for planting in the subsequent season and for selling when prices become favorable. Most of the marketable surplus food grain of farmers, traders and millers is stored by using two systems, the bag system, which is the prevalent mode of storage, and the bulk system where bulk facilities (silos) are available. A major cornerstone in this challenge is the competition from insect pests particularly in the tropics and sub-tropics, where the climate provides a highly favorable environment for a wide range of insects. Stored grain infestation is a very serious problem as various life stages of insects cause economic damage and deteriorates the quality of food grains and food products. There are a number of stored grain insect pests that infest food grains in farmer stores and public warehouses and massively surge due to un-controlled environmental conditions and poor warehousing technology used (Sarwar, 2008; 2009; Sarwar and Sattar, 2007; 2012).

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Insects infesting stored foods are one of the most common household pest problems. There are many different kinds of insects that invade stored dried foods, they contaminate more food than they consume, and most peoples find the contaminated products unfit for consumption. Food store pests are often discovered when they leave an infested food to crawl or fly about the house. They often accumulate in pots, pans or dishes or on window sills. Fortunately, they do not bite or sting to peoples or pets nor do they feed on or damage the house structure or contents. Nearly all dried food products are susceptible to insect's infestation, including cereal products (flour, cake mix, cornmeal, rice, crackers and cookies); seeds such as dried beans and popcorn; nuts; chocolate and other dried fruits; spices; powdered milk and cured meats. Non-food items that may be infested include birdseed, dry pet food, ornamental seed and dried plant displays, ornamental corn, dried flowers, garden seeds, and rodent baits. A stored food product may become infested at the processing plant or warehouse, in transit, at the store, or right in the home. Most of the stored food insects also are pests of stored grain or other commodities and may be relatively abundant outdoors. Food products that are left undisturbed on the shelves for long periods are particularly susceptible to infestation; however, foods of any age can become infested. Stored food insects are capable of penetrating unopened paper, thin cardboard, and plastic, foil, or wrapped packages. They may chew their way into packages or crawl in through folds and seams. Insects within an infested package begin multiplying and can spread to other stored foods or food debris that has accumulated in corners, cracks and crevices, and eventually the entire cupboard. All stages (egg, larva, pupa, and adult) may be present simultaneously in infested products (Siddiqui and Sarwar, 2002; Sarwar et al., 2004; Ali et al., 2009; 2011).

2. Danger Signs

Stored food insects attack includes sighting of live insects, damaged product or packaging material, holes in packaging materials, insect feeding evidence on product, and webbing in products (product clumped together due to insect webbing).

3. The Type of Storage Designs

There are two basic storage designs for protecting grains and seeds from the insect problems which infest grain in the fields, or can fly into stores responsible for the food losses. There are cheap and low technology designs for stores which keep food and seeds safe. In regions with long dry seasons, the narrow crib is successful in dry regions. It is required, timber for 6 legs, 9 long frame units, 8 cross frame units, nails, corrugated metal roofing sheets, and 6 metal cones (cut from metal plate). In regions with long rainy seasons, and high humidity, a bin, made from metal or cement is common in small and large farms. The drum must have a well-fitting special-shaped filling lid, and emptying vent.

4. Insect Pests of Stored Foods

Stored food pests though are found in almost every home or market, yet only few peoples recognize why stored product pests occur and how to identify them. Many insects are transported into the homes from a store or warehouse and others originate in the home when susceptible items are stored for long periods of time. Finding the same insect repeatedly in the home is a good indication of a stored product pest's problem. Recognizing the pest can help to narrow down likely sources of the infestation. Thus, this article contribution is designed to help to identify some of the more common stored food product pests.

5. Types of Food Insect Pests

Food insect pests may be divided into primary and secondary pests. Primary grain insects have the ability to attack whole, unbroken grains, while secondary pests attack only damaged grain, dust and milled products.

5.1. Primary Food Pests

Primary pests attack and breed in previously undamaged cereal grains and pulses. They also feed on other solid but non-granular commodities, but they are rarely successful on milled or ground foodstuffs. Primary pests are usually more destructive than secondary pests, especially in short-term storage.

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

The lesser grain borer is the most serious pest of stored food, and it is a dark brown cylindrical beetle about 3 mm long. The head is hidden by the thorax when viewed from above. Females lay up to 500 eggs scattered loosely through the grain. The eggs hatch to produce curved white larvae with brown heads and three pairs of legs. The larvae burrow into slightly damaged grains and eat out the starchy interior. After pupating the adults emerge from the grain, leaving large irregular exit holes. The life cycle takes from three to six weeks depending on the temperature. Adults may live up to two months. The adult lesser grain borers chew grain voraciously causing damage which may facilitate infestation by a secondary pest. It is a strong flyer and may rapidly migrate from infested grain to begin new infestations elsewhere. This is also a destructive pest causing damage

throughout the many countries. Adults and larvae feed inside the grain, thus reduce the weight and degrade the quality. The lesser grain borer is most abundant in humid climates and whenever the moisture content of wheat is high.

5.1.2. Granary, Rice and Maize Weevils (*Sitophilus* spp.)

Weevils are slender insects with a conspicuous snout projecting forward from the head. They are dark brown, sometimes with four orangish spots on the wing covers. Larvae are white, legless, and look wrinkled and are only found inside whole kernels or seeds. These weevils attack only whole grains or seeds, leaving small round exit holes in infested kernels. They rarely are found in nuts, dried fruits, macaroni, and caked or crusted milled products such as flour. Granary weevil (*Sitophilus granarius*) (Linnaeus) when disturbed, it sits very still for several minutes and an adult lays up to 450 eggs singly in holes chewed in cereal grains. Each egg hatches into a white, legless larva, which eats the grain from the inside. The larva pupates within the grain and the adult then chews its way out. The exit holes are characteristic signs of weevil's damage. The life cycle takes about one month under summer conditions and adults may survive for a further eight months. The granary weevil is a small dark brown-black beetle about 4 mm long with a characteristic rostrum (snout) protruding from its head. It has biting mouth parts at the front of the rostrum and two club-like antennae.

An adult rice weevil (*Sitophilus oryzae*) (Linnaeus) lays up to 450 eggs singly in holes chewed in cereal grains and each egg hatches into a white, legless larva, which eats the grain from the inside. The rice weevil has four orange-brown areas on the wing cases, and is about 3 mm long with a characteristic rostrum (snout) protruding from its head. It has biting mouth parts at the front of the rostrum and two club-like antennae. Unlike the granary weevil, the rice weevil is winged and may occasionally fly.

5.1.3. Angoumois Grain Moth (*Sitotroga cerealella*) (Oliver)

The angoumois moth is yellow-brown with darker markings and its wingspan is 12-20 mm. Females lay up to 250 eggs on or near the surface of stored grain. The eggs hatch into a caterpillar which bores into grain kernels remaining inside until matures. It then eats its way out of the grain, leaving characteristic exit pin holes on the grain surface. Unlike to most other moth pests, no surface web is formed. The life cycle may be completed in as little as five weeks. As well as reducing the weight of grains, angoumois moth infestations impart an unpleasant smell and taste to the cereals.

5.2. Secondary Pests of Stored Food

Secondary pests are able to attack only materials that have been previously damaged either by other pests **(**primary pests) or by poor threshing, drying and handling. They also attack processed commodities such as flour and milled rice, where they may form the majority of insect presences.

5.2.1. Flour Beetles (*Tribolium confusum* and *Tribolium castaneum*)

Flour beetles are reddish-brown, and elongate oval in shape, larvae are cylindrical, whitish, or cream-colored and have two small pointed spines on the tail end (the larvae are not usually noticed by residents). Flour beetles infest many types of dried food products, such as flour, bran, cereal products, dried fruits, nuts and chocolate. Two species of flour beetles may be found in food, red flour beetles are common in homes and the confused flour beetle is a frequent pest in flour mills. The confused flour beetle (*Tribolium confusum* Jacquelin du Val) closely resembles the rust-red flour beetle in appearance and life history except for the antenna segments which do not have a distinct three-segmented club at the end. It is more often found in flour mills than on farms, as it prefers more finely divided materials.

Rust-red flour beetle (*Tribolium castaneum*) (Herbst) is frequently found on farms and it is a reddish brown beetle about 3 mm long. The final three segments of its antennae are greatly enlarged to form a club shape. Young adults are pale brown in color becoming darker with age. Females lay up to 1000 eggs loosely scattered throughout infested grain. Cream-colored larvae with biting mouth parts and three pairs of legs hatch, and remain free from the grain, feeding on cereal dust and damaged grains. A generation takes about one month to complete under summer conditions, but longer in cold weather. The adult is winged and may fly and can live up to a year.

5.2.2. Saw-toothed Grain Beetle (*Oryzaephilus surinamensis*) (Linnaeus)

The saw-toothed grain beetle is common on farms and adults are dark brown to black with six tooth-like projections on each side of the thorax. These lay up to 500 eggs loosely spread through the infested grain; eggs hatch to produce larvae which feed externally on grain dust and sometimes wheat embryos. Larvae are cream-colored, slender and these are rarely noticed by residents. The mature larvae pupate within a silken cocoon and a complete generation may takes place in as little as three weeks, but the adults may live up to nine months. These frequently hide in cracks and crevices of buildings and machinery. Saw-toothed grain beetles are found in many different food items, including dried fruits,

cereals, nuts, dried meat, macaroni, and seeds. They are easily identified by the saw-like teeth on each side of the thorax.

5.2.3. Flat Grain Beetle (*Cryptolestes ferugineus*) Steph

Flat grain beetles are small reddish brown insects about 1.5 mm long with long antennae and a flattened body. Eggs are laid throughout the stored grain and develop into tiny larvae with characteristic tail horns, biting mouth parts and three pairs of legs. These feed on damaged grain and wheat embryos. Pupation takes place in a cocoon and a complete life cycle takes from 4-5 weeks and adults may survive up to one year.

5.2.4. Warehouse Moth (*Ephestia elutella*) (Hubner)

The warehouse moth is a drab grey insect with a 10-12 mm wingspan and it usually only infests the surface of stored grain. Moths live for only about two weeks, but during that time lay up to 200 eggs. These are distributed loosely on the grain surface. Larvae hatch out of the eggs and wander over the grain surface leaving a trail of silk which may form a thick mat covering on the surface of the infested grain. Mature larvae pupate in a silk cocoon among the grain or on the walls of the building. The life cycle takes at least four weeks to complete.

5.2.5. Indian Meal Moth (*Plodia interpunctella*) (Hubner)

The adult Indian meal moth is grey with distinctive brownish-red tips to the forewings. The female lays up to 200 eggs near the grain surface as it slowly passes from grain to grain spinning a silk thread. Severe infestations may form a surface web on the grain heap. Larvae attack the wheat germ, and then pupate in a cocoon which may be found in cracks and crevices of buildings. The insects quickly emerge as adult moths and a generation takes as little as four weeks under warm conditions to complete. The larvae are whitish worms with shades of yellow, pink, green, or brown and only the larvae feed in stored products, which can be any dry stored food or whole grain. Foods infested with these insects can have silk webbing present on the surface of the product. Larvae often leave the food when mature and may move long distances before stopping to spin a cocoon. It is common to find caterpillars and cocoons on ceilings and walls of store. Adult moths may be seen up to several weeks after the food source has been removed.

5.2.6. Khapra beetle (*Trogoderma granarium*) Everts

It is a widespread but sporadic pest and causes extensive damage in conditions of high humidity and high moisture content. The khapra or warehouse beetle is a pest of stored grain in its own right, but the greater threat is the impact on trade that it could have by masking an incursion of the world's worst pest of stored grain. Warehouse beetles require microscopic examination to distinguish them. Khapra beetle when does occur anywhere, it would have a severe impact on international profession if it became established. Eggs are usually laid in crevices and under the surface of loose food, which hatch in about a week and only the larval stage damages grain. It is frequently found in seeds, groceries and used sacks. The larvae are conspicuously hairy and usually live for about five weeks, but may enter a dormant phase (diapause) for more than two years. Larvae may moult up to ten times and after pupation adults emerge and these are less obvious than the larvae and do no damage to grain. These live for up to five weeks during which females lay up to 80 eggs. Warehouse beetles cannot fly and are spread only in infested commodities and old sacks. A characteristic of warehouse beetle infestations is the accumulation of cast larval skins. Hairs shed by larvae may cause asthma, skin or gastric problems. These beetles feed in a wide variety of food products, such as grain products, seeds, dried fruits, animal by-products skins, fur, hair and pet food.

6. Prevention and Control Program

Massive efforts are required to suppress population densities of the different pests in order to achieve an adequate supply of food. The reduction in losses can be attributed to use of appropriate pest-control techniques (admixture of chemical protectants with stored grain), and improved storage structures and design. Farmers seldom practice chemical pest-control methods due to the small volume of grains stocked and fast turnover of stocks (Francisco et al., 2009). Common ways to pests control are purchase of dried foods in quantities small enough to be used up in a short period of time. Refrigerate or freeze small amounts of highly susceptible foods. Keep food storage areas clean and do not allow crumbs or spilled food to accumulate. Remove and discard old, unused products and inspect the remainder. Thoroughly clean cracks and corners with a vacuum cleaner and also check and clean areas where pet food and birdseed are stored. Washing with detergents, ammonia, or bleach cannot prevent insect infestation. There is no evidence to prove that placing bay leaves or sticks of spearmint gum in a cupboard can prevent or deter stored food insect pests. For proper pest elimination, locate the source of the infestation, carefully examine all susceptible foods, look at the top surface of the product with a flashlight or pour the package contents onto a cookie sheet. Throw away all foods that are infested and if infested material is to be salvaged (for

example, birdseed) or if infestation is questionable, heat the product in shallow pans in a 130 degrees oven for at least 30 minutes, or place in the freezer at 0 degree for at least 4 days. Thoroughly, clean and empty the cabinets and shelves with a vacuum cleaner (especially cracks and corners) to pick up crawling insects and spilled or infested materials. Empty the vacuum cleaner or discard the vacuum cleaner bag after use to prevent re-infestation. Washing shelves with detergent, bleach, ammonia, or disinfectants cannot have any effect on insect pests. As a precaution against re-infestation, consider storing of susceptible foods in sealable glass, metal, or heavy plastic containers or in the freezer or refrigerator until it is convinced that the infestation has gone. It is typical to see an occasional Indian meal moth flying for as long as 3 weeks after the source of caterpillars has been eliminated. Insecticide sprays are not recommended for controlling insects in stored food cupboards. Household insecticides have no effect on insects within food packages and any control is temporary unless the source is found and eliminated. If insects are infesting ornaments or decorations made with plant products or seeds, place the items in a freezer for 4 days (Sarwar, 2004; 2010; 2013; Sarwar et al., 2013).

Insect populations of many species have evolved resistance to insecticides as a result of the widespread use of these chemicals in pest control. In some cases, insects which have only been exposed to one insecticide develop resistance to other related compounds. Therefore, it is important that insecticides resistance should be prevented from spreading. This may be achieved by an appropriate use of pesticides and by farm hygiene. This consists of careful cleaning of all machinery and buildings used for storing and transporting grain right from the header to the port terminal (Sarwar, 2015 a; 2015 b). Other, common ways to pests control are:-

6.1. Keeping of Bins Clean and Repaired

Sanitation is the key to prevent food pest problems, never store new grain on old grain, and mix it with old grain or store it in a dirty bin. Old grain and debris are the most important sources of insects that attack new grain. Completely remove and burn all old grain, broken kernels and other debris. Clean anywhere the spilled grain that may have accumulated, including outside the bins, behind partitions, between walls and under floors. Fill any holes to prevent access by birds and rodents. Check the roof, as moisture from rain and snow can encourage insects development. Clean harvest and grain-handling equipment before harvest. Avoid storing grain near feed storage, animal feeders or stables as these areas may be sources of grain infesting insects.

6.2. Use of Residual Sprays

After cleaning, treat all bin surfaces, including removable doors, behind partitions, and under floors, with an approved insecticide about two weeks before storing new grain. The dosage can vary with the porosity of the surface being treated. Malathion may not be effective where Indian meal moth is a problem. Remove insects killed by this treatment to avoid contaminating new grain.

6.3. Store Cleaning and Drying of Grain

Moisture of corn should be less than 15 percent; while for other grains it should be at 12 percent or less. Minimize cracked kernels and other dockage as they allow some grain pests to build up at much lower temperature than are required with whole grains.

6.4. Aeration of Grain

Proper aeration of the grain ensures uniform temperatures and thus avoids moisture buildups that encourage mold development. Molds directly affect grain value and they also serve as alternate food sources for some grain pests, which increases the insect problem.

6.5. Protection of the Grain

Insecticides may be used to treat grain as it is moved into storage. Check the label for proper dosages. These materials also may be used to treat the surface of the grain to provide a protective barrier against infestation. This barrier is broken whenever the surface is disturbed, such as during inspections for insects, so, retreatment is recommended after inspections.

6.6. Inspect of Grain Regularly

Below 55 to 60 degrees ^{o}F, inspect grain every two weeks and above this temperature, inspect it weekly. This can detect new infestations early and avoid extensive damage. Use a grain probe to take samples in a systematic pattern first from the surface (horizontally, about 2 inches deep) and then from the bottom of the grain mass. Inspect both the center and the area near the walls with samples no farther apart than 20 feet.

7. Suppression of Insect Populations

For suppression of multiplying insect populations, highly specific and more appropriate modern methods ought to be used. Few important methods such as microwave and ionizing irradiation, pheromone baited traps, and use of entomopathogens are proved highly effective against stored grain insects. Over these methods, repellents and oviposition inhibitors isolated from various plant species are considered

as much safer in comparison to synthetic pesticides. These natural pesticides have no side effect and are biodegradable in natural environment. However, non-residual, non-persistent and less toxic bio-organic pesticides should be used that may not affect the quality of food grains. Besides this, low pressure and low temperature treatments are proved much safer pest management tools that represent a potential alternative of fumigants to control coleopteran and lepidopteran insects. However, for an effective control of stored grain insects various parasitoids, predators, pathogens and other living organisms are employed in natural conditions to suppress the pest populations. For better protection of stored grain, control computer based decision support system should be used to predict damage and operation requirements for a timely control. In addition, both biological and non-biological factors and their effects must be evaluated to check the possible infestation during storage. Therefore, selected control strategies must be integrated for effective management of stored grain insects (Upadhyay and Ahmad, 2011).

To sum up, the pest control measures should be designed at the onset of grain storage if the food is planned to be stored for more than 30 days. Traditional grain storage facilities may not offer protection, but promotion of the use of metal silos and resistant varieties for grain storage is an alternative approach to reduce losses (Adda et al., 2002; Tadele et al., 2011). The drying of the foods helps in reducing the moisture content to about 9-12% in the drier areas, thus, minimizing the activities of storage insect pests and pathogens (Okunade et al., 2001).

8. Conclusion

Deterioration and contamination from the presence of insects result in downgrading of grain and market value due to pest body parts, odors, molds and heat damage. For this reason, the local and overseas customers demand insect-free food grains. Firstly, locate the infestation source (or sources) and then the source of infestation is eliminated properly. After that, seal all un-infested foods in air-tight containers such as screw-top glass, heavy plastic or metal containers. Also, seal all other food products that might become infested in tight containers. Ordinary metal kitchen canisters are not tight enough to exclude some insects. Food store pest problems can usually be avoided by using all dried food within 2-4 months of purchase. Spices and other products that are to be kept for longer periods should be sealed in airtight containers. When peoples buy packaged foods, check that the bags or containers are well sealed. Keep food storage areas clean and clear of crumbs or food particles. Pet food is a major source of stored product pests, so, be sure to store pet foods in well-sealed buckets or storage containers. With heavy or widespread infestations, it may need to apply an insecticide spray to empty cupboards, drawers and pantries. All food products, utensils and containers should be removed from the treatment area before spraying. Sprays must be allowed to dry before placing clean shelf paper on the shelves and returning food items back.

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