Post-harvest Insect Pests of Cereal Grains and their Management Strategies

Reem Mohammad

After harvest, the majority of the grain is stored for periods that may be long or short, depending on the purpose of storage. During the post-harvest period, grain is typically stored in warehouses that meet appropriate storage conditions to keep the seeds as viable and intact as possible. However, grain in warehouses is susceptible to numerous pests (insects, fungi, mites, rodents, etc.). Insect pests constitute a large group of stored grain pests. These infestations may originate from the field. In this case, the insect is a pest of both the field and the warehouse. Consequently, it can easily be transported with the harvested grain to the store, from where it can spread to healthy grains. Infestations may also be present in the warehouse itself due to ineffective pre-storage sterilization, or due to the presence of entry points for insects that can cause new infestations at any time. Therefore, preventive measures are paramount in warehouses. If insect infestation is detected in a store, it is essential to accurately diagnose the infestation, identify the insect causing the damage, its stage, and the density of its population. It is also necessary to assess the damage rate and the severity of the damage to determine the most appropriate measure to manage the specific pest. Therefore, this chapter reviews the most important points related to post-harvest insect pests of grains and how to deal with them.

Keywords: *Infestation, Insect pest, Detection management, Post- harvest, Stored grains*

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Introduction

Cereal crops constitute the staple food for a large portion of the world's population. As population growth increases, so does the demand for food in general, and grains in particular. The process of producing grains and their products goes through many stages, starting with preparing the seeds for planting, preparing the soil, caring for the crop during its growth, protecting it from pests and unfavourable environmental factors, and finally harvesting and post-harvest storage, which is a very sensitive stage because it requires great concern to protect the previous efforts that brought the crop to this stage. In storage, the crop may be exposed to many unfavourable conditions, some of which may be caused by abiotic factors such as temperature and relative humidity... etc. and some of which may be caused by biotic factors such as insects, fungi, rodents, etc. Among biotic factors, insects are one of the biggest threats to stored grains. Stored grain insects are characterized by their broad feeding range, enabling them to be present in all areas of the storehouse or surrounding area as long as food is available.

They also have a relatively short life cycle, meaning that once an insect infestation occurs, the population density increases rapidly, resulting in significant quantitative and qualitative losses. Through periodic examination, the presence of an infection is identified and diagnosed. Diagnosis of the infestation depends on several factors, including observing signs related to the insect itself (its stages, feeding remains, molting and pupation remains, thread webs) and symptoms appearing on the infested grains (perforated grains, irregularly imperfect grains, clumps, powder at the bottom of storage containers). In addition to the quantitative loss of grain stock due to insects, they also negatively impact grain quality. Their feeding on grains leads to a decrease in nutritional value due to a decrease in carbohydrate, protein, and amino acid content.

Their waste also results in an increase in grain temperature, creating an environment conducive to the growth of mould and the toxins that result from it, which are harmful to human health. To avoid grains infestation by insects and to deal optimally with infestations if they occur, it is necessary to be aware of the insect species common in stored grains and their feeding habits, understand the sources of infestation, and conduct periodic inspections and assess the damage in order to make the optimal decision to manage the situation.

Classification of post- harvest cereal insect pests
Scientific classification

Based on specialized knowledge of insect orders and families, the insect pests causing damage to stored grains and their products could be attributed to at least two basic orders: Lepidoptera and Coleoptera. Table 1 lists the most important insect pests infesting grains in storage (Upadhyay & Ahmad, 2011; Ahmad et al., 2021).

Table 1. List of Post-Harvest Insect Pests of Cereal Grains

Common name	Scientific name	Order: Family
	Grain weevils	
Rice weevil	*Sitophilus oryzae* (Linnaeus, 1763)	Coleoptera: Curculionidae
Granary weevil	*Sitophilus granarius* (Linnaeus, 1758)	Coleoptera: Curculionidae
Maize weevil	*Sitophilus zeamais* (Motschulsky, 1855)	Coleoptera: Curculionidae
Broad-nosed grain weevil	*Caulophilus oryzae* (Gyllenhal, 1838)	Coleoptera: Curculionidae
	Grain borers	
Lesser grain borer	*Rhyzopertha dominica* (Fabricius, 1792)	Coleoptera: Bostrichidae
Larger grain borer	*Prostephanus truncatus* (Horn, 1878)	Coleoptera: Bostrichidae

Grain and flour beetles		
Saw-toothed grain beetle	*Oryzaephilus surinamensis* (Linnaeus, 1758)	Coleoptera: Silvanidae
Square-necked grain beetle	*Cathartus quadricollis* (Guérin-Méneville, 1844)	Coleoptera: Silvanidae
Foreign grain beetle	*Ahasverus advena* (Waltl, 1834)	Coleoptera: Silvanidae
Flat grain beetle	*Cryptolestes pusillus* (Schoenherr, 1817)	Coleoptera: Silvanidae
Siamese grain beetle	*Lophocateres pusillus* (Klug, 1832)	Coleoptera: Trogositidae
Cadelle beetle	*Tenebroides mauritanicus* (Linnaeus, 1758)	Coleoptera: Tenebrionidae
Confused flour beetle	*Tribolium confusum* Jaqcquelin du Val, 1863	Coleoptera: Tenebrionidae
Rust-red flour beetle or red flour beetle	*Tribolium castaneum* (Herbst, 1797)	Coleoptera: Tenebrionidae
Long-headed flour beetle	*Latheticus oryzae* Waterhouse, 1880	Coleoptera: Tenebrionidae
Slender-horned flour beetle	*Gnathocerus maxillosus* (Fabricius, 1801)	Coleoptera: Tenebrionidae
Broad-horned flour beetle	*Gnatocerus cornutus* (Fabricius, 1798)	Coleoptera: Tenebrionidae
Tobacco beetle or Cigarette beetle	*Lasioderma serricorne* (Fabricius, 1792)	Coleoptera: Anobiidae
Drugstore beetle or Biscuit beetle	*Stegobium paniceum* (Linnaeus, 1758)	Coleoptera: Anobiidae
Black carpet beetle	*Attagenus unicolor* (Brahm, 1791)	Coleoptera: Dermestidae
Larger cabinet beetle or Khapra beetle	*Trogoderma granarium* Everts, 1898	Coleoptera: Dermestidae
Glabrous cabinet beetle or Colored cabinet beetle	*Trogoderma glabrum* (Herbst, 1783)	Coleoptera: Dermestidae
Cowpea weevil or Cowpea seed beetle	*Callosobruchus maculatus* (Fabricius, 1775)	Coleoptera: Chrysomelidae
Chinese bruchid or Cowpea bruchid	*Callosobruchus chinensis* (Linnaeus, 1758)	Coleoptera: Chrysomelidae
Bean weevil	*Acanthoscelides obtectus* (Say, 1831)	Coleoptera: Chrysomelidae
Mealworms		
Yellow mealworm (European meal worm)	*Tenebrio molitor* Linnaeus, 1758	Coleoptera: Tenebrionidae

Dark or black mealworm	*Tenebrio obscurus* Fabricius, 1792	Coleoptera: Tenebrionidae
Grain moths		
Angoumois grain moth	*Sitotroga cerealella* (Olivier, 1789)	Lepidoptera: Gelechiidae
Rice moth	*Corcyra cephalonica* (Stainton, 1866)	Lepidoptera: Pyralidae
Fig-almond moth	*Cadra cautella* (Walker, 1863)	Lepidoptera: Pyralidae
Flour moths		
Indian meal moth	*Plodia interpunctella* (Hübner, 1813)	Lepidoptera: Pyralidae
Mediterranean flour moth	*Ephestia kuehniella* Zeller, 1879	Lepidoptera: Pyralidae
Meal snout moth	*Pyralis farinalis* (Linnaeus, 1758)	Lepidoptera: Pyralidae

Classification by feeding nature

This criterion depends on whether the insect feeds on previously infested grains or only healthy grains. It can be classified into:

Primary insect pests: These insects feed on intact grains stored under good storage conditions. They do not feed on broken grains, grains previously infested by other insects, ground grains, or other imperfect grains.

They can be classified into two categories based on their site of the feeding stage:

- **External feeders**: feed outside the grain and their stages are located and develop outside the grain, such as: red flour beetle, khapra beetle, etc.

- **Internal feeders:** feed during at least one of their stages inside the seed, where that stage is located and develops. Such insects include: rice weevil, lesser grain borer, etc.

Secondary insect pests: The members of this group feed on unhealthy grains, including those that are already infested, broken, or ground, etc. Such insects: Saw toothed grain beetle, long headed flour beetle, flat grain beetle, etc. (Deshwal et al., 2020; Ahmad et al., 2021).

Source of infestation

The presence and spread of many insects is linked to the environmental conditions. All stored product insects have a wide range of hosts that they can feed on in the absence of their preferred hosts. They can also be found in the store walls' cracks, previously used storage bags, harvest waste, bird nests, etc. Therefore, once the conditions become favourable for the insect, its population density increases dramatically, causing significant infestations in both quantity and quality. Storage pests move from infested areas or hiding places to the crop in many ways. Several stored grain pests have been documented as having spread from the field to the storage. These pests are typically primary pests, with adults having strong flight capabilities, unlike secondary pests, which have poor flight capabilities and have not been observed in the field.

Many conditions pave the way for the infestation spread from the field to the warehouse, such as the proximity of fields to storage areas or the movement of workers between the field and the warehouse without following preventive measures, as well as climatic conditions that may contribute to the spread of the infestation. An example of this case: angoumois grain moth, rice weevil, maize weevil, lesser grain borer, pulse beetle. Many farmers store grains in previously used bags, these bags may contain insects from the previous crop, making it highly likely that the infestation will spread to newly stored grain. Machineries used for crops' post- harvest treatment may in turn cause the infestation to be transmitted to the next product, such as the Mediterranean flour moth, which is transmitted in mills through machineries. Under certain climatic conditions, flying adults of some insects (e.g. angoumois grain moth, Indian meal moth, red flour beetles and rice weevil) may move from storage to the field or vice versa, setting the stage for a new infestation. Many stored grain pests (e.g. khapra beetle) are transported long distances during trade by trucks, trains, or ships. The long duration of transportation can contribute to increased pest population density in the event of even a minor infestation. Grain threshing yards also contribute significantly to the transmission of the disease to storage areas. Cracks and openings in storage buildings often provide a breeding ground for insects, especially if there are remnants of previously stored materials that have not been completely disposed of. Also, some stored product insects (e.g. carpet beetle) may take refuge in birds' nests and rodent burrows at inopportune times (Kumar, 2017).

Kind of Infestation

Infestations may occur when insects move from the field to the storehouse during the post-harvest period. This is called a horizontal infestation. When the infestation spreads within the storehouse between bags and stacks, it is called a vertical infestation. Insects may already be present in the storehouse before storage, and infestations occur later when a new crop is put into storage. This infestation is called a latent infestation. Finally, when multi-feeding insects move from one crop to another, it is called a cross-infestation (Kumar, 2017).

Detection of stored grain insect infestation

Insect infestations of grain stored at home or in warehouses cause significant damage, both quantitatively and qualitatively, by contaminating the grain with their droppings and creating an environment conducive to mould growth. They also reduce the nutritional value of stored products. Therefore, early detection of infestations is crucial to avoiding the damage caused by subsequent infestations. Below are some methods used to detect infestation in grain stores. The simplest way to detect infestation is to take samples manually, where the species of the insect pest, if present, is determined through one of its stages, its droppings, or the damage symptoms, in addition to determining the seed damage percentage and the infestation severity. Other simple and commonly used methods include probes and insect traps (e.g. pitfall trap), various models of which have been developed and are generally used to detect the presence of adults. Probe traps are used to estimate insect densities at various depths in grains. The traps should be monitored periodically, and any adults collected in the trap removed. These traps provide approximate estimates of the insect population density. Pheromone traps (based on sex pheromone or aggregation pheromone) are also a useful method relying on manipulating chemical communication between insects to attract adults or disrupt mating. The effectiveness of these traps depends on prevailing environmental conditions, such as temperature, rainfall, wind direction, etc. Pheromones of *Rhyzopertha dominica*, *Trogoderma granariumare* and *Tribolium castaneum* are commercially marketed and used worldwide. Another type of trap used is light traps, which rely on the attraction of adults to light based on the wave properties of light.

Some research has indicated the use of sounds emitted by insect movement and feeding to detect insects in grains by filtering and refining the sounds without the need for sampling (acoustical method). The results of this method depend on the physical and biological characteristics of the insects emitting the sounds. Chemical detection methods are also effective, which depend on detecting insect secretions during feeding, egg laying, etc., such as ninhydrin method to detect the infested grains and acid fuchsin staining method to detect the egg plug of the rice weevil in the seed surface. Some studies have indicated other methods that use X-rays and infrared rays to detect warehouse insects, but these methods are very expensive (Kumar, 2017; Ahmad et al., 2021).

Management of stored grain insects

Effective control of stored grain pests involves a combination of different approaches within the framework of integrated pest management (IPM), and these include:

Physical method

Controlled Atmosphere (CA) storage

This strategy relies on manipulating gas levels in the storage atmosphere, particularly oxygen and carbon dioxide, to reduce respiration rates and thus inhibit insect and fungal growth while preserving seed viability. Since the metabolic processes of living organisms require oxygen, reducing the oxygen level in the storage atmosphere over a specific period will reduce insect activity and growth, ultimately leading to death. Likewise, increasing the level of carbon dioxide will kill insects of all stages. Studies have shown that increasing the level of carbon dioxide in the warehouse atmosphere is more effective than decreasing the level of oxygen. Implementing this strategy requires conditions similar to those applied in fumigation, requiring a tightly sealed atmosphere, ventilation after the process is complete, and taking the necessary safety measures during and after the process (Navarro, 2012; Olorunfemi & Kayode, 2021). For example, Shankar et al. (2022) tested the effectiveness of applying carbon dioxide gas at different concentrations on different stages of the pulse beetle (*Callosobruchus maculatus*) in black gram grain stored in sealed 25 kg bins at different exposure times. Table 2 exhibits the main results.

Temperature

Many storage insects cannot tolerate extreme temperatures. The optimal temperature for the growth of most insects ranges between 25-35°C. Therefore, insect growth and activity decrease at temperatures outside this range. Then, applying high temperatures of 50-60°C in empty storage areas will kill existing insects. Regarding low temperatures, the temperature required to kill insect pests varies depending on the insect species and stage. Generally, 0°C is sufficient to kill most stored grain insects. Ventilating the grain also helps expose existing insects to varying temperatures, which aids in better management (Upadhyay & Ahmad, 2011; Kumar, 2017; Bareil et al., 2018).

Table 2. CO_2 concentrations and exposure times causing 100% mortality of *C. maculatus* different stages

Stage	CO_2 Concentration%	Exposure Time (hrs.)
Eggs	50	72
Larvae	60	48
Pupae	70	96
Adults	20	48

Moisture

The moisture content of stored grains plays an important role in the growth, development, and reproduction of insects. The ideal R. H. for insect growth in storage ranges from 12-15%. Therefore, proper storage moisture control (R. H. ≤ 12%) will help preserve seed integrity and create unfavourable conditions for insect presence (Kumar, 2017; Olorunfemi & Kayode, 2021).

Sanitation and exclusion

These procedures include storing grains after harvest in clean areas. The warehouse must be sterilized before storage to ensure that no insects from previously stored crops remain, especially in cracks or openings in the walls. Clean bags and bins must be used, and old ones previously used for grain storage must be sterilized. Harvesting, transportation, and handling equipment, as well as all post-harvest equipment's, must also be sterilized. It is preferable to keep raw grain storage areas away from finished product storage areas. Doors and windows should be designed to prevent the movement of insects into and out of the warehouse as much as possible, and to ensure the effectiveness of fumigation when applied (Upadhyay & Ahmad, 2011; Kumar, 2017).

Inert dusts

Inert dust is used to effectively control warehouse pests. For example, silicon dioxide, diatomaceous earth, minerals (e. g. dolomite, rock phosphate, magnesite, calcium carbonate, sodium chloride, etc.), sand, wood ash, clays, paddy husk ash, etc. (Kumar, 2017; Guru et al., 2022).

Irradiation: Eliminating stored grain insects using radiation (such as gamma rays, infrared rays, etc.) in controlled doses is an effective and globally approved method for grain storage management (Kumar, 2017).

Cultural methods: Cultural procedures in storage differ from those in the field. Generally, it is preferable to harvest grains after they are fully ripe to ensure proper storage. Treating the crop with a systemic insecticide before harvest can also help protect stored crops from insect infestations for a period of time (Upadhyay & Ahmad, 2011; Kumar, 2017).

Legislative methods: Legislative measures ensure, as far as possible, that insect infestations are not transmitted between goods during commercial transactions, whether domestic or international, through plant quarantine laws and other agreements with the same purpose (Kumar, 2017).

Mechanical methods: Mechanical methods are used to monitor and control insects in storage areas by catching them using various types and mechanisms. Entoleter, which is a device relies on the centrifugal principle, is also used to separate healthy grains from those infested with insects (especially those in advanced stages) (Kumar, 2017).

Host plant resistance: Through host plant resistance, numerous efforts are being made to produce grain varieties that are resistant to insect damage during storage. Some of these contribute to increasing the hardness of the shell, while others increase the release of volatile substances that repel insects, and other grain properties that hinder insect feeding (Kumar, 2017).

Biological and microbial methods: Biological control agents (parasitoids, predators and pathogens) can be used to control stored grain insects, whether used prophylactically in stores before or during storage to protect grains and grain products. For example: The egg parasitoid *Trichogramma* sp. is very common against moths' eggs. The larval parasitoid *Habrobracon hebetor* is effective in managing *P. interpunctella, E. kuehniella* and *C. cautella* in the storage. The larval parasitoid *Holepyris sylvanidis* is highly effective against *T. confusum*. The warehouse pirate bug *Xylocoris flavipes* is a predator of eggs and immature stages of many stored grain insects. The entomopathogenic bacteria *Bacillus thuringiensis* has been used in many countries to control lepidopteran insects in storage (Kumar, 2017; Harush et al., 2021; Guru et al., 2022).

Plant products (Botanicals): Under closed warehouse conditions and due to the nature of storage and the sensitivity of the stored materials, plant-based insecticides (botanicals) that have volatile aromatic properties are an effective and safe option in all respects. Botanicals can be used in the form of dry powders, aqueous or solvent extracts, essential oils (Eos), etc. Botanicals have several effective properties in managing storehouse insects, they act as repellents, anti-feeding agents, anti-oviposition agents, growth regulators, hormonal regulators, chemo-sterilizers, etc. Depending on the characteristics of each plant species, the insect species, and the properties of the stored grains, the form and method of using botanicals can be determined. Insect repellent pellets (IRPs) containing combination of the active compounds of essential oils can be an ideal alternative to chemical pesticides. IRPs containing oils from lemongrass, eucalyptus, and neem leaves have been used effectively to control the red flour beetle, *T. castaneum* (Mangang & Manickam, 2022). Treating wheat grains with neem seed kernel powder (NSKP), chilli dried fruit powder or calotropis leaf powder at 50gm/kg seeds is effective in managing the rice weevil (Mohammad et al., 2024). The EOs of *Piper betle* (betel) and *Pelargonium graveolens* (geranium) with LC_{50} values of 12.58 and 18.01 mg/ dm^3, respectively are recommended to manage *C. cephalonica* by fumigation, while they prove their efficacy on eggs and adults of the rice moth (Sowmya et al., 2023). Although many essential oils have been tested for effectiveness against various stored grain insects, only a few have been commercially approved. This is due to some properties that limit its effectiveness, such as its rapid volatility, susceptibility to rapid decomposition, and poor solubility in water. Currently, integrating nanotechnology with essential oils (Nano-encapsulation and nano-emulsion) is a promising option that can help improve their water solubility, bioactivity, and stability, helping control their release and expand their range of action (Chaudhari et al., 2021; Maurya et al., 2024). Peppermint essential oil (PO) encapsulated in chitosan nanoparticles (CS NPs) improve sustained controlled release and enhances the insecticidal activity of Peppermint essential oil against *T. castaneum* and *S. oryzae*, having a higher acetylcholinesterase activity than pure oil (Rajkumar et al., 2020).

Behavioural methods: This area of pest management aims to manipulate insect behaviour related to feeding, mating, communication between individuals, etc. Chemicals that affect insect behaviour are called semio chemicals and can be divided into two categories: those with long-rang effects, such as repellents and attractants, and those with short-rang effects, such as feeding deterrents or inducers. Some long-rang techniques involve using attractants combined with traps, such as pheromones or food attractants specific to a particular insect species for mass-trapping. Combining pheromones and food attractants is preferable to using either alone. The pheromone can also be combined with an effective insecticide in traps for mass-killing purposes. This method reduces the cost and harmful effects of using chemical pesticides alone. Another of these techniques is the mating distraction technique, which aims to disrupt mating and prevent the laying of fertilized eggs. It relies on exposing insects to a high concentration of pheromone, which confuses the insect and diverts it from the correct mating path, i.e., creates a fake path. Many chemicals also have insect repellent properties and can be used effectively in warehouses.

Examples of these include those of plant origin (botanicals), which are environmentally friendly, safe for human health, and effective against warehouse pests. Short-rang techniques include feeding deterrents, which work to prevent the insect from feeding, prevent the female from laying fertilized eggs, or prevent the female from visiting the egg-laying site. Many plant species, their extracts, or compounds have demonstrated this effect. Feeding stimulants are also used for insect management, an example being the combination of microbial pesticides and feeding stimulants to improve the insect's ability to take up a sufficient dose of microbial pesticide (Upadhyay & Ahmad, 2011; Kumar, 2017).

Chemical methods: As for insecticides, they are used as a last resort in the event of severe infestation and when rapid and effective intervention is necessary. Given the specific nature of stored grains and their products as direct human food, frontal contact of pesticides with the grain is undesirable due to its known negative effects. Therefore, fumigation, which does not require direct contact with the grain and can reach insects wherever they are found, represents the preferred method of using insecticides in storage. There are generally three forms of fumigants: gaseous, liquid and solid, where the liquid and solid transform into a gaseous state upon contact with air.

Commonly used incense fumigants include: Methyl Bromide (MB), Carbon Tetrachloride, Carbon Disulfide, Ethylene Oxide, Phosphine, Hydrogen Cyanide, Chloropicrin, Essential Oils. Each of these fumigants has specific chemical and physical properties and biological effects, and therefore each has specific recommendations for use regarding the dosage used, safety during and after use, its effect on seed viability, and other factors (Upadhyay & Ahmad, 2011; Kumar, 2017; Ahmad et al., 2021). In general, methyl bromide gas is not preferred for use due to its negative effects on the ozone layer. Instead, it is preferable to use phosphine gas, which is effective in controlling grain insects in stores at a concentration of (500-600 ppm) for a period of up to 60 days (Arora & Srivastava, 2021). Nanotechnology contributes significantly to the protection of stored grains due to its unique properties that enhance the effectiveness of insecticides, such as altering electrical conductivity, surface chemistry, and reactivity. For this purpose, various metal oxides are manufactured in the form of nanoparticles, such as zinc, silica, aluminium, silver, etc. *Bt*-coated zinc oxide nanoparticles (*Bt*-ZnO NPs) causes a decrease in female's fecundity and hatchability of *C. maculatus* in addition to prolonging the overall developmental period (LC_{50}= 10.71 μg/ml) (Malaikozhundan et al., 2017).

New insecticides represent a significant advance in pest control having unique mode of action with less harmful environmental impact than older ones. New insecticides include several classes, the most prominent of which are the spinosyn group containing spinosad and spinetoram which are produced from fermentation of two species of *Saccharopolyspora* and used effectively in storage for managing insect pests. This group shows greater selectivity towards target insects and less risk to non-target organisms, making it a more suitable choice in grain stores than other, more hazardous pesticides (Kirst, 2010). Spinosad is effective against many stored grain insects with varying efficacy. Spinosad is very effective in managing *R. dominica*, as its application to grains at a dose of 0.25 ppm for 7 days achieves a mortality rate ranging from 94.5- 100% (Perišić et al., 2022). The combination of new insecticides and nanotechnology offers a promising solution for eco-friendly insect pest management.

The combination of spinosad and graphene enhances the mortality rate of the studied storage insects, with a significant reduction in the subsequent offspring (Lampiri et al., 2025). Spinetoram is effective as a grain protectant in managing insect pests in stores. Its effectiveness depends on the concentration used, the exposure time and the insect species, as illustrated in Table 3 (Vassilakos et al., 2012; Vassilakos & Athanassiou, 2023).

Table 3. Spinetoram concentrations and exposure times causing specific mortality% against different storage insects

Insect species	Mortality%	Concentration (ppm)	Exposure time (days)
Rhyzopertha dominica	100	0.1	7
Prostephanus truncatus	100	0.1	7
Tribolium confusum	95	10.0	14
Oryzaephilus surinamensis	95	5.0	14
Sitophilus oryzae	100	1.0	14
Sitophilus granarius	100	0.5	14

Conclusion

Since grain crops constitute the staple food for many countries, especially developing ones, maintaining the quantity and quality of the crop is essential to meeting the growing demand for grains and food products. Therefore, post-harvest grain storage is the most critical phase of the process. Therefore, ensuring the cleanliness of storage areas and equipment used after harvest is extremely important. Furthermore, it is essential to continuously monitor and inspect stored grains to ensure immediate intervention if any infestation is detected. If an insect infestation is identified, the optimal control method is chosen in accordance with the infestation conditions and in accordance with the integrated pest management program, which ensures the protection and preservation of stored grains with minimal economic, environmental, and health damage.

Conflict of interest

The authors declare that they have no conflict of interest

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