Control Strategies

2-Physical control

by temperature, moisture, pressure, and aeration system:

Manipulation of the physical environment and application of physical treatment are the two methods under physical control. **Storage temperature, the moisture content in the stored grain,** relative humidity, and relative composition of gases (O2, CO2 etc.) in the intergranular spaces are the components that define the physical environment and can be controlled to reduce infestation level.

Temperature treatment is the best physical method that kills several life stages of different insects at a time.

a-Low-temperature treatment: Generally, the optimal temperature required for stored grain insect pests ranges from 25-33°C. Low temperatures can reduce the rate of development, feeding, fecundity, and survival of insects.

Temperature control in the stored grain in the form of supercooling and superheating can alone help to suppress insect infestation without use of insecticides. The temperature maintenance is a sensitive issue as there

remain chances of moisture condensation in the grain mass. This method will prove to be more effective if used as a protective measure rather than curative.

b**) High-temperature disinfestations:** High temperatures can kill insects. There are many ways to increase the temperature in stored grain to achieve disinfestation like

hot air convection, infrared microwave radiation, counter-flow heat exchangers, high-frequency waves, and solar radiation. Temperature should be carefully controlled while disinfesting the grains so that the grains are not damaged by heat. The selection of the proper heating method will depend on the capital cost and energy efficiency of various systems. Generally, all stored grain insects can be killed by increasing the grain temperature to 60-65°C that can be achieved by using a cost-effective heating method which uses hot air in a grain drier. However, one must be careful that high temperatures can reduce germinability and the quality of seeds in many cases (wheat, barley, etc.). Neeson and Banks (2004) suggested a potential technique known as bake-out for heating the storage structure to about 50°C for about one day.

c) Pressure: Low pressure is a potential non-chemical pest management tool as it creates a low oxygen-controlled atmosphere to kill stored grain insects. In all stored flour insects, combination of low temperature and high pressure were not as much effective as combination of high temperature and low pressure.

d) Use of aeration system: Grains meant for storage should be aerated well after harvest to keep the grains dry and to reduce moisture migration. Appropriate aeration should be ensured to prevent condensation of moisture in the grain considering the grain characteristics and the configuration of storage structure.

e) Pneumatic conveyer: Cyclone- based grain pneumatic conveyers (also called pneumatic grain augers or grain vacs) can control insect infestation. The percussion effect created by the cyclone causes insect mortality but high grain volume can reduce the effectiveness of this method.

3-Inert dust, sands, and silica gels:

Inert dust can kill insects by physical effect rather than chemical means as this is unreactive dust. Insects die due to dehydration and desiccation when they come into contact and get coated with desiccation materials.

Five types of inert dust can be used for the safe storage of grains

1-Sands and other soil particles are popularly and traditionally used for making a protective barrier on top of the stored seed.

2- Diatomaceous earth (DE): DE is obtained from unicellular aquatic algae that have opaline silica ($SiO_2 + n H_2O$) in the cell wall. DE can be modified chemically to increase its efficiency. The most effective DE modification is CaDE which acts as insecticide, repellent, and voiced against pulse beetle. DE has low mammalian toxicity and therefore, can be used for managing stored grain pests.

3- Silica aerogel: It is a light non-hygroscopic powder consisting of sodium silicate.

4- Non-silica dust like rock phosphate and lime (calcium oxide) also provide some control.

5- Particle films (Kaolin and bentonite clays).

Inert dust is advantageous;

1- it is non-chemical in nature and provides long-term protection from insect infestation.
2- It does not affect grain quality such as the baking quality of wheat grains or the nutritional or functional value of grains.

4-Ionizing irradiation:

There are two types of radiation (gamma radiation AND beta radiation)

which can be generated to control insects in an environment-friendly approach in storage. Gamma radiation obtained from radioactive isotope such as cobalt-60 and Beta radiation that is an electrically generated beam of electron are the ionizing radiations which kills insects by producing highly reactive free radicals and charged molecules inside the insect body.

Generally, a high dose is required to cause immediate death of insects and a lower dose causes sterilization of many species. The dose of radiation differs depending upon the insect species. The penetration power of the ionizing radiations also differs. Beta radiation has lower penetration power (only 0.6 cm) than gamma radiation (30 cm). Ionizing radiation can kill all the life stages of insects and leave no harmful residues in the grains.

The advantages and disadvantages of irradiation with beta rays

Advantages

1-The system can be readily automated.

2-Safe to the operators, if proper safety protocols are followed.

3-All life stages of insects can be killed.

4-No harmful chemical residues are left in the grain and grain temperature is increased only less than 0.1°C.

5- Nutritional values are unaffected at low doses.

Disadvantages

1-High capital cost.

2-Low penetration power.

3-Adult-stage insects continue to live for some time.

4-There is no residual protection from future re-infestation from external sources.

5-The seed is killed by the irradiation required to control insects.

5. Ozonation:

The use of ozone is a potential alternative to conventional systems of sterilizing grains. Ozone can be used for fumigation in storage structures and can kill insects in food grains at levels lower than 45 ppm.

The disadvantage of using ozone in storage grain is that it is corrosive to most of the metals.

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6. Behavioural control by using pheromones:

Pheromones can be used in storage for surveillance, monitoring, and mass trapping of insects by attractants. These are required in minute quantities to prepare traps to be placed in warehouses. It is being used for capturing and killing *Trogoderma* by using 14-methyl 8-hexadecimal as the primary component of bait traps. Wheat germ oil in combination with sex pheromone can be used to attract and trap khapra beetle larvae.

7. Control by natural plant products:

Plant extracts known as biocide or green pesticides can be a substitute source of chemical pesticides due to their safe, eco-friendly, inexpensive, and easy to use with more compatible properties without the appearance of pest resistance.

Advantages.

1-They get degraded rapidly in nature

2-Leaving no harmful residues.

3-They also have low mammalian toxicity and are commonly available.

4-Antifeedant action for the control of stored grain pests.

5-Plant products can provide prolonged protection to grains when used for small scale application or for space treatment.

Many plant species from families like **Annonaceae, Asteraceae, Canellaceae, Labiatae, Meliaceae etc** extracts. Insecticidal properties of plant extracts such as *Piper nigram, Anetham graveoleons , Allium sativum , Vitex negundo and Polygonum hydropiper and Myristica fragrans* have been established against stored grain pests. However, the use of some carrier gases like CO2 can help in the even distribution and penetration into stored commodities.

The toxicity of extracts to insects varied in

1- relation to the type of the plant

2- extract type.

3- exposure time and doses.

For instance, different parts of the plants (leaves, peel, seeds, fruits) can be used and washed carefully by water, air dried in shade and ground into fine powder through using electric grinder that can be used to control the insect pest either as a powder or liquid assay (in water or ethanol) and then preparing a serial dilution.

8. Biological control of stored grain insects:

Due to problems associated with chemical control, emphasis nowadays has been placed on alternatives such as biopesticides. **This is the use of living organisms to minimize the undesirable effects of pests by reducing the pest population. Living organisms used as biological control include parasitoids, predators, and pathogens. The pathogen includes microorganisms such as fungi, nematodes, protozoa, bacteria, and viruses.** In natural conditions, various parasitoids, and predators occur in stored product ecosystems and these species can be explored as biological control agents.

A. Parasitoids

Parasitic wasps (Order: Hymenoptera) Parasitoid wasps are small wasps most are winged and have complete metamorphosis. The junction between the thorax and abdomen is constricted to form a waist.

Major families associated with stored products are

1-Family: Ichneumonidae ***Venturia canescensen***

is internal parasitoids that attack the larva of

plodia interpunctella , Ephestia spp, Corcyra cephalonica

2-Family: Braconidae ***Habrobracon hebetor***

is internal parasitoids that attack the larva of

plodia interpunctella , Ephestia spp, *Corcyra cephalonica*

3-Family: Bethylidae ***Cephalonomia*** **spp**

is external parasitoids that attack the larva of

lasioderma sericorne, stegobium paniceum, Sitophilus spp, *Oryzaephilus surinamensis.*

4-. Family: Trichogrammatidae ***Trichogramma*** **spp**

is internal parasitoids that attack the egg of wide ranges of moth species.

Some species of wasps are parasitoids of the eggs and larvae of beetles and moths in stored products. However, for many stored products the presence of any insects is commercially unacceptable. Recently there has been more interest in using parasitic wasps to control pests under

conditions of farm storage. Release of wasps have also been undertaken to control remaining populations of insects in factories and in empty storage structure

B. Predators:

The warehouse pirate bug ***Xylocoris flavipes*** was reported to suppress the population of moths upto79-100% in small storages of peanuts whereas.

The cosmopolitan predator Xylocoris flavipes predated upon several pests such as *Tribolium castaneum, T. confusum, Crytolestes pusillus, Rhizopertha dominica and Trogoderma granarium* Validation studies are necessary for determination and proper prescription of the biological control agents to replace the protectant insecticides in stored grain pest management. Several studies need to be conducted further to collect enough data related to parasitoids and predators for their effective deployment in warehouses and/or feed mills.

C. Microbial control:

An adequate level of pest control can be obtained from alternate methods of insect management like the use of microbial that contain microorganisms or their by-products like **toxins or spores.**

Advantages of Microbial;

1-They are safe for both the pesticide user and consumers

2- due to their less toxicity to non-target animals as well as humans.

This entomopathogens can be successfully used for the control of invertebrate pests in glass houses, row crops, orchards, ornamentals, stored products, and forestry. To enhance the killing power of pathogens against stored product insects.

-Bactria;

Botanical extracts in combination with ***B. thuringiensis*** caused a significant enhancement to the pathogens which in turn increased mortality of stored product lepidopteran insects like *Plodia interpunctella*, *Ephestia cautella and E. kuehniella* as well as different coleopteran pests of stored wheat.

Fungal

species like ***Beauveria bassiana, Lecanicillium lecanii, Metarhizium anisopliae and Paecilomyces farinosus***

all were reported to have pathogenic action against Indian meal moth and cowpea weevils. Use of gunny bags covered by foams treated with a combination of formulated mustard oil and fungi like *Paecilomyces fumosoroseus* have resulted significant reduction in ovipositional and adult emergence in Bruchidius incarnates.

Desiccant dust were recorded to have a synergistic effect when combined with *B. bassiana* and used for control of stored.

Granulosis virus (GV) can be used to control *Plodia interpunctella* (Indian meal moth).

For greater effectiveness of microbial pesticides, several things need to be looked at such as

1- formulation of the product.
2- timing and method of application
3- storage condition of the treated grains. Heat, desiccation, andexposure to UV radiation lessen the effectiveness of microbial pesticides.

9. Insect growth regulators (IGR):

Insect hormones and their analogs can be used to control grain insect pests. IGRs cause abnormal morphogenesis in insects by

1-affecting embryonic and post-embryonic development.

2- as well as other biological processes like reproduction and behavior.

Insect growth hormones are most successfully used in closed environments against several stored product moths and beetles. Many of the IGRs are have proven to be more potent (even against insect eggs) than some currently used insecticides. **hydroprene. methoprene** , both of these compounds reduced the population of adult of some pests. For post-harvest protection of stored foods, there is now renewed interest in development of risk free, low toxic alternatives like IGRs for replacement of conventional products being used so far. IGRs could be added to baits containing attractants for better results instead of directly to food. To facilitate IGRs performance as a surface treatment agent, the identification of physical and biological factors is necessary that compromise their efficacy

10. Use of proper storage structures:

The grains are stored in bulk (loose grain storage) or bags (sacks), the latter being common in the tropics because of ease in handling, more flexibility, and low capital requirement. Various structures are used in different areas and are known by different names.

All the structures should have the following pre-requisites:

1- It should be made up of easily available cheap materials to suit the people of rural areas where such structures are prevalent.

2- The site for the storage structure should have a proper sanitation facility.

3- The environment within the structure should restrict the supply of ample oxygen and should reduce temperature fluctuations.

Modern storage structures which are designed and developed using scientific principles and techniques have

been useful to store food grains safely for long periods. Such structures are Gharelu thekka, Flat bottom metal bins, Hopper bottom metal bins, composite bins, etc. White-painting in storage bins can reflect heat and keep the grain inside cooler. The acquaintance of the farmers with efficiency can result in extra income for them by selling quality produce when prices are favorable to them.