

Scientific management of insect infestation during storage of minor millets

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On the occasion of International Year of Millets 2023, the nutri-cereals/ minor millets are getting special attention in diet. Previously the production was limited for these crops due to several reasons, however the nutritional benefits and the hardy adaptation made these crops popular day-by-day. Apart from production, the storage of these grains also needs to be taken care. Insects are the major culprits of the storage losses of millets. Management of these grains for their safer storage is the need of hour. This article provides the list of important insects infesting millets during storage and their scientific management to minimise the losses.

Keywords: Insects, Millets, Management, Nutri-cereals, Storage

INDIA is one of the largest producers of millets in the world, with a long history of millet cultivation. This includes various types of millets such as pearl millet, finger millet, sorghum, and small millets like foxtail, proso, and kodo millets. Among these, pearl millet is the most widely grown millet in India, accounting for ~50% of the total production. It is mostly grown in the states of Rajasthan, Haryana, and Uttar Pradesh. Finger millet, another important millet, is mostly grown in Karnataka, Tamil Nadu, Andhra Pradesh, and Telangana. Minor millets are the sub-group wherein they are less concentrated these days. They are mainly grown in India and other parts of Asia and Africa. They are often referred to as 'nutri-cereals' due to their high nutritional value, especially in terms of protein, dietary fibre, and micronutrients. They are also considered to be more resilient to climate change and pest attacks than other major cereal crops.

The seven important minor millets are Foxtail millet (*Setaria italica*), Little millet (*Panicum sumatrense*), Kodo millet (*Paspalum scrobiculatum*), Barnyard millet (*Echinochloa* spp.),

Proso millet (*Panicum miliaceum*), Brown top millet (*Brachiaria ramosa*) and Finger millet (*Eleusine coracana*).

According to the Ministry of Agriculture and Farmers Welfare, the total production of millets in



Important minor millets of India

India during 2020-21 was estimated to be around 28.7 million tonnes. The total production of minor millets in India during 2019-2020 was around 3.9 million tonnes, with Tamil Nadu being the largest producer (1.3 million tonnes) followed by Karnataka (1.0 million tonnes) and Andhra Pradesh (0.6 million tonnes). The production of minor millets in other states such as Maharashtra, Gujarat, and Telangana was also substantial. In recent years, there has been renewed interest in millets due to their health benefits and the potential they hold for improving food security and sustainable agriculture. The Indian government has also launched various schemes and initiatives to promote millet cultivation and consumption, including the Millets Mission under the National Food Security Mission.

Storage scenario of minor millets

In India, there are several government agencies responsible for regulating and monitoring the storage and distribution of millets. These agencies work together to ensure the proper storage and distribution of millets and other food grains in India, and to support

the development of a sustainable and equitable agricultural system. Major ones are Food Corporation of India (FCI), National Agricultural Cooperative Marketing Federation of India (NAFED), State Agriculture Marketing Boards (SAMB), Agricultural Produce Market Committees (APMCs), and Warehousing Development and Regulatory Authority (WDRA).

The approximate share of storage out of production of minor millets in India varies depending on several factors such as the crop, location, and storage capacity. Generally, it is estimated that 5-15% of the total production of minor millets in India is stored, with majority of the grain being consumed or sold immediately after harvest. FCI is responsible for maintaining adequate storage facilities for various food grains including minor millets, and as of 2019, the FCI had a total storage capacity of around 76.5 million tonnes. However, the actual utilization of this capacity varies, and it is estimated that the utilization rate for minor millets is much lower than for other major crops like rice and wheat. Additionally, farmers often store small quantities of minor millets in their homes or in local community storage facilities for personal consumption or to sell in the local market. The exact amount of storage at this level is difficult to estimate, but it is a common practice in rural areas. In summary, the share of storage out of production for minor millets in India is relatively low compared to major crops like rice and wheat, but it is an important aspect for ensuring food security and stability of prices for these nutritious grains.



Millet storage in a warehouse
(Raipur, Chhattisgarh)

Need of safe storage

Proper storage of millets is important to maintain their quality, nutritional value, and to prevent insect infestation and mould growth. Few basic things to be concentrated are:

- **Cleaning and drying:** Millets should be cleaned and dried thoroughly before storage to remove any dirt, debris, or moisture. Any damaged or discoloured grains should be removed to avoid contamination.
- **Airtight containers:** Millets should be stored in airtight containers made of food-grade material such as plastic, glass, or stainless steel to prevent moisture, insect infestation, and exposure to air.
- **Cool and dry place:** Millets should be stored in a cool, dry place away from direct sunlight and heat sources such as stoves or ovens. The ideal storage temperature for millets is below 25°C, and the relative humidity should be less than 70%.
- **Pest control:** Millets should be checked regularly for any signs of insect infestation or mould growth. Using natural pest control methods such as neem leaves, garlic, or bay leaves can also help in preventing insect infestation.
- **Shelf-life:** The shelf-life of millets varies depending on the type and storage conditions. Generally, millets can be stored for up to 6-12 months if stored under proper conditions. It is recommended to consume millets within 3-6 months of storage for optimal quality and nutritional value.

In India, there are several major storage locations for millets storage. Andhra Pradesh is a major producer of millets and having several storage locations across the state. Karnataka is also having a well-established storage site for millets in major locations like Bengaluru, Hubli, and Mysuru. Rajasthan is major producer of pearl millet and focussed on other millets storage. Maharashtra and Tamil Nadu also

have storage facilities. In addition to these states, there are several other locations across India where millets are stored, including major ports such as Mumbai, Chennai, and Kolkata, where millets are imported and exported.

Storage losses

Varieties of biotic and abiotic factors affects the quality of millets kept for storage. Few of the important ones are as follows:

- **Moisture content:** High moisture content in millets can lead to fungal growth, insect infestations, and other types of deterioration. Millets should be dried to an appropriate moisture level before storage (preferably <12%), and the moisture content should be monitored regularly during storage to prevent excessive moisture uptake.
- **Storage temperature:** Millets should be stored at cool and dry conditions. The recommendations are as per rice and wheat storage.
- **Type of storage:** Poor quality containers or packaging that are not airtight can lead to moisture uptake, insect infestations, and other types of spoilage. In India, the storage is conventionally done in gunny bags and metal bins.
- **Duration of storage:** The longer the millets are stored, the higher the risk of storage losses.
- **Handling and transportation:** Proper handling and transportation practices are important to prevent physical damage to the millets, which can lead to secondary damages later.

Among various abiotic and biotic factors, insects can cause significant damage to millets during storage. They can feed on the grains, contaminating them with excreta, and making them susceptible to fungal growth and mould infestation. Consumption of millets by insects during storage can cause quantitative losses, leading to reduction in the total quantity of grains. The feeding will also result in loss of nutrients, including protein,



Insect infestation and damage caused by insects in minor millets
(a&b – Rice moth; c&d – Lesser grain borer; e&f – Red flour beetle).

vitamins, and minerals. This can reduce the nutritional value of the grains. In addition, the infestation results in contamination of millets with their excreta and body parts, leading to a reduction in the quality of the grains. Infested millets may have a foul odour, off-flavour, and a discoloured appearance, making them unsuitable for human consumption.

Physical damage is one of the most common quality losses caused by insect feeding on millets. Insects such as the rice weevil (*Sitophilus oryzae*) and lesser grain borer (*Rhyzopertha dominica*) can cause damage to the surface of the grains, resulting in the loss of the outer layers of the seed coat. This can lead to a reduction in the size and weight of the grains, as well as an increase in the number of broken and fragmented kernels. The physical damage caused by insect feeding can also increase the susceptibility of the grains to mould and fungal growth, which can further degrade the quality of the grains.

Insect feeding can also result in chemical changes in millets, including the breakdown of carbohydrates, proteins, and lipids. Insects such as the Angoumois grain moth (*Sitotroga cerealella*) can produce digestive enzymes that can break down starch and sugars in the grains, leading to a reduction in their nutritional value. In addition, insect feeding can increase the free fatty acid content of millets, which can cause rancidity and off-flavours in the grains. These chemical changes can reduce the palatability and nutritional quality of millets and make them less desirable for human consumption.

Microbiological contamination is another quality loss caused by insect feeding on millets during storage. Insects can create openings in the grains, allowing moisture to penetrate and creating favourable conditions for mould and fungal growth. These microorganisms (especially *Aspergillus* spp.) can produce toxins, such as aflatoxin and ochratoxin, that can pose a

health risk to humans and animals. In addition, the presence of mould and fungi can cause discoloration and off-odours in the grains, further reducing their quality and making them unsuitable for consumption.

Insects infesting millets in storage

In general, stored products of agricultural and animal origin are attacked by more than 600 species of coleopterans, 70 species of lepidopterans and about 355 species of mites. They are causing both quantitative and qualitative losses. Unlike other crops, the insects damaging the stored grains, many times get access from the field and get established at the storage site. Additionally, they also come due to cross infestation by infested lot/grains and added with the processing and handling. The detailed list of insects infesting stored products are readily available. The important insects infesting stored millets are given in Table 1.

Management options

Preventive measures

- Preventive measure of any insect infestation avoids the major proportion of the insect management. Harvesting at proper time, is the very basic step in insect management. Harvesting at the right time helps minimize grain damage during handling while preserving the nutritional value of the grains, thereby reducing the risk of insect infestation.
- Drying of the grains to a moisture range of 10 to 12% based on grain type, avoid majority of the damage. Drying can be done under sunlight or using any developed dryers. Sometimes the initial infestation observed in field can be managed by exposing the grains in sunlight for shorter period.
- Proper cleaning and scientific drying of the grains after harvesting should be done, simultaneously adjust the harvesting equipment for minimum kernel or seed damage and maximum cleaning.
- Proper sanitation of the storage

Table 1. Insects infesting stored millets

Name of the insect	Photo	Life cycle	Type of damage
Grain weevils - <i>Sitophilus</i> spp. (Rice weevil – <i>Sitophilus oryzae</i> ; Mazie weevil – <i>Sitophilus zeamais</i>)		Adults can live for several months, females laying 300 – 400 eggs loosely throughout the grain. Life cycle completed in 3 weeks at 30 – 33°C, 17 weeks at 20°C, reproduction stops below 17.5°C.	Internal and Primary pest
Lesser grain borer – <i>Rhyzopertha dominica</i>		The life cycle takes from 3-6 weeks depending on the temperature. Adults may live up to two months.	Internal and Primary pest
Angoumois grain moth - <i>Sitotroga cerealella</i>		The life cycle may be completed in as little as five weeks. Females lay up to 250 eggs on or near the surface of stored grain.	Internal and Primary pest
Indian meal moth - <i>Plodia interpunctella</i>		Four to eight weeks. The female lays up to 200 eggs near the grain surface as it slowly passes from grain-to-grain spinning a silk thread.	External and Primary pest
Flat grain beetle - <i>Cryptolestes pusillus</i>		Life cycle completes in 4 weeks at 30 – 35°C with moist conditions. Females lay up to 300 eggs loosely in the grain stack.	External and Secondary pest
Red flour beetle - <i>Tribolium castaneum</i>		Life cycle completed in 4 weeks at 30°C, 11 weeks at 22°C. Adult's life is 200 days to 2 years and fly in warm conditions. Can lay up to 1000 eggs per female, loosely scattered throughout the commodity.	External and Secondary pest
Rice moth – <i>Corcyra cephalonica</i>		Complete life cycle is 26 days (warm) to 75 days (cooler). The female will lay 100 to 200 eggs.	External and Secondary pest

structure. Avoid spillage during handling of grains. Clean the grains completely, avoid the foreign matter and debris to reside over the grains during handling. If grading is done

- prior to storage, it will be useful. Disinfestation of bulk and bag storage structures using insecticides is also important practice to be done prior to storage and a layer of insecticide

spray can be suggested immediately after storage. Since, dichlorvos and malathion are not available for using in warehouses, deltamethrin is the only available options for

disinfectant and for surface sprays.

- **Storage temperature:** The storage temperature of minor millets should be maintained at below 25°C to prevent insect infestation and mould growth.
- Minor millets should be stored in airtight containers to prevent moisture uptake and insect infestation. The use of food-grade packaging materials such as polypropylene bags or vacuum-sealed plastic bags is recommended. The packaging should be checked regularly for any signs of damage, and damaged packaging should be replaced immediately to prevent contamination.
- Regular monitoring of the quality of stored minor millets is essential to identify any issues that may arise during storage. The quality of the grains can be assessed based on parameters such as moisture content, insect infestation, mould growth, and mycotoxin contamination.

Curative measures

- **Storage climate management:** This includes the modification of the storage temperature by heat or cold treatment. Use of structures which withhold lower pressure are of greater importance in storage. Mortality of insects achieved by hypoxia and dehydration. Normal growth and development of each insects require a range of favourable atmospheric conditions (25-32°C). Deviations from this optimum ranges, negatively affects the insect metabolism. Grain disinfestation using thermal treatments was conventionally practiced using hot/cool- air/water, in a controlled condition. Advances in this field included dielectric heating of grains using radio frequency (RF) and microwave (MW) heating.
- **Advanced storage methods** include the scientific storage techniques like hermetic technology. The concept of creating a barrier between the

commodity and grain with a concept of deoxygenation inside storage structure to reduce the aerobic condition. This reduction in O₂ concentration, elevate the CO₂ which affect the metabolic activity of the insects, ultimately leading to death. In India, few such hermetic bags are developed recently and are available in Indian markets, viz., Save Grain Bags®, Grain Pro®, Ecotact bags®, Super Grain Bags® and others.

- Inert dusts like diatomaceous earth have proved effective against stored-grain insect pests.
- Plant derivatives or botanicals are one more option. These acts like repellents, antifeedants, toxicants, chemosterilants, growth regulators, etc. because of the active ingredients present in them. There are variety of herbal tablets available in market with these active ingredients.
- Essential oils extracted from different plant-based groups are also effective. Plant families like Meliaceae, Myrtaceae, Apiaceae, Lamiaceae, Lauraceae, Poaceae, Pinaceae, etc. are reported to contain insecticidal secondary metabolites/ volatiles like terpenoids, alkaloids, phenolics, etc. The dosages range from 2g to 15g per kg of food grains. Impregnation of these essential oils are also being done in conventional storage bags and used in many storage studies across the world.
- **Physical trapping devices:** Various traps including light traps are available in market for the warehouse usage. The UV traps are effective in mass trapping the adults of these beetles. However, they are

non-selective and have safety limitations.

- Entomopathogenic fungi like *Beauveria bassiana*, *Metarhizium anisopliae* and bacterium - *Bacillus thuringiensis* (Bt) were also tested against stored-grain pests especially beetles. For the stored-grain moths, Bt was registered long back but commercial application has limitations.
- Biotic agents like predators and parasitoids are also effective and sustainable options. Few of them are naturally available. However, the method has its own limitations of right-time and right quantity availability, regional adaptability, and their handling.
- Semiochemicals like pheromones and allelochemicals are also available synthetically for *Plodia* and *Tribolium*. They can be used to mass trap the adults of these pests.
- **Chemical methods:** There are ready references dealt with the chemical protectants used in grains and storage structures (NSPM-22, 11, 12, 15). Chemical insecticides are used in two ways i.e., prophylactic sprays and curative treatments. Prophylactic sprays are left with only one option for these days i.e., Deltamethrin. The dosage and recommended values are given in Table 2. For fumigation, presently, aluminium phosphide (ALP) is the molecule available for large scale fumigation to control stored produce pests effectively. Generally recommended @ 3 tablets per tonne of food grains (each tablet is 3g and can release 1g of phosphine gas). The



Different hermetic bags available in Indian markets

Table 2. Dosage and recommended values for prophylactic sprays

Chemical name	Group	Concentration	Dilution	Dosage of prepared solution	Remarks
Deltamethrin	Synthetic pyrethroid	2.5% (W.P)	40 g/L	3 L/100 sq.mt	To be sprayed on the surface of jute bags of stored foodgrains once in three months

* Previously listed chemicals like DDVP and Malathion were withdrawn from usage and are not available.

fumigation period is 7 days and minimum aeration of 5 days.

SUMMARY

Scientific management of food grains is always important to preserve nation's food security.

Nonetheless, millets also need attention during storage to avoid their losses because of various biotic agents like insects. Primary and secondary insects infesting millets during storage can cause significant damage. Their management

includes both the preventive and curative steps which are to be taken care at various times. Moisture management is one such critical factor, apart from maintenance of the climate inside storage structures. Use of chemical insecticides became the key management strategy which involved prophylactic sprays and fumigation. Overall, looking at the increasing importance of millets, one can also concentrate on safer storage of millets to achieve food security.

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