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Grain storage systems and insect management in Punjab (north India)

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Abstract

A food bowl of India, Punjab contributes 17% to wheat and 12% to rice production per year from the country's 3% of the net sown area. The grains thus produced are either moved along the supply chain to meet the market demands or are held under storage for future use. The types and conditions of storage structures are the most important factors in handling and storage of food grains. In Punjab, a part of the produced grains is generally stored at farm level, in structures like Bukhari (3.5 to 18 tonnes) made of mud and bricks, earthen egg shaped Bharola (40-80 kg) and galvanized metal bins (PAU model - 0.15 to 1.5 tonne). The large amount is stored commercially by government agencies or hired storage structures that accounts for 14.6 million tonnes (Mt) in warehouses, uncovered Cover and Plinth (CAP) structures and silos. Major storage is done by agencies such as: Punjab State Warehousing Corporation (covered: 5.22 Mt and uncovered: 1.03 Mt), Food Corporation of India (covered: 4.43 Mt and uncovered: 2.41 Mt), Central Warehousing Corporation (1.26 Mt) and silos (FCI and private sector 0.25 Mt). About 97% of the commercial storage is done in bags (made of jute or polypropylene woven) under covered or uncovered conditions either inside warehouse or CAP storage as compared to 3% in bulk modernized silos. The biotic agents like beetles (Coleoptera) and moths (Lepidoptera) are the common insects attacking grains under storage deteriorating the quality and affecting the quantity of stored grains. The effective management of these insects found under the prevailing storage conditions is a major challenge in Punjab, presently relying on earlier developed storage protocols for fumigation (Aluminum phosphide at 3 tablets of 3 g each/tonne with polythene cover on grain stack, for shed fumigation at 21 tablets of 3 g each/28 m^3); along with prophylactic sprays, i.e., every 15 d with Malathion 50 EC (Emulsifiable Concentrate), and every three months with Deltamethrin 2.5 WP (Wettable Powder). The structures are built in such a way that aeration is carried out by opening opposite doors of the warehouse, side wall vents, and roof turbo vents. In farm level small scale storages, plant extracts such as from neem, black pepper, turmeric, and sweet flag are being used (dosage at 10 g extract/kg of grains). Research on the effect of abiotic, biotic factors, physical methods, and stored product entomology in specific grain storage of Punjab is meagre, which limits insect management and results in significant use of chemical fumigants and insecticides.

Keywords: Fumigation, Grain storage, Insects, Insecticides, Storage structures, Punjab, India, Aluminum phosphide

Introduction

In Punjab, a province (state) of India, about 75% of the state population depends directly on agriculture and about 97% of the total cultivable area is used for crop production. Punjab is popularly known as the 'Food Basket of the Country' or 'Granary of India', because of its contribution to wheat (17%) and rice (12%) production from the country's 3% of the net sown area. Punjab produces 2% of the world's wheat and 1% of rice. India's position as the second largest producer of food grains for decades has been possible due to the contribution of Punjab. Punjab produced 30.73 million tonnes (Mt) of food grains in 2020, which was 57% of India's wheat, 41% rice, and 4% other grains like pulses and oilseeds (Anonymous, 2020). The record food grain production in Punjab is driven by having the greatest area of fertile land, availability of water (99% of Punjab area is successfully irrigated), and higher adaptation of agricultural mechanisation compared to other Indian states. A national study conducted by ICAR-CIPHET, Ludhiana reported post-harvest losses of 4.7% in food grains (Nanda et al. 2012); however, losses can be much higher and even 100% of the grain output could be unfit for consumption by humans and animals in case of poorly managed grain storage in Punjab. On average, 75% of food grains stored in Punjab is mainly by central and state government agencies, and 25% is stored at farm level by farmers for consumption and seed purposes. The sound food grain storage management of procured grains is a very important activity, but is often neglected due to insufficient storage capacity in Punjab whereby grains become more vulnerable to the vagaries of climate and insects, which in turn causes huge post-harvest losses. This paper discusses the status of food grain storage facilities, common insects found in storages, and their existent management in Punjab.

Status of grain storage in Punjab

Stored grain is a living entity that respires and decays with time and, hence, demands safe storage systems and processes. The types and conditions of storage structures are the most important factors in the handling and storage of food grains. In Punjab, a smaller volume of produced grains is generally stored at farm level, and the larger volume is stored commercially by central and state government agencies in warehouses, CAP or in hired storage structures (Fig. 1).

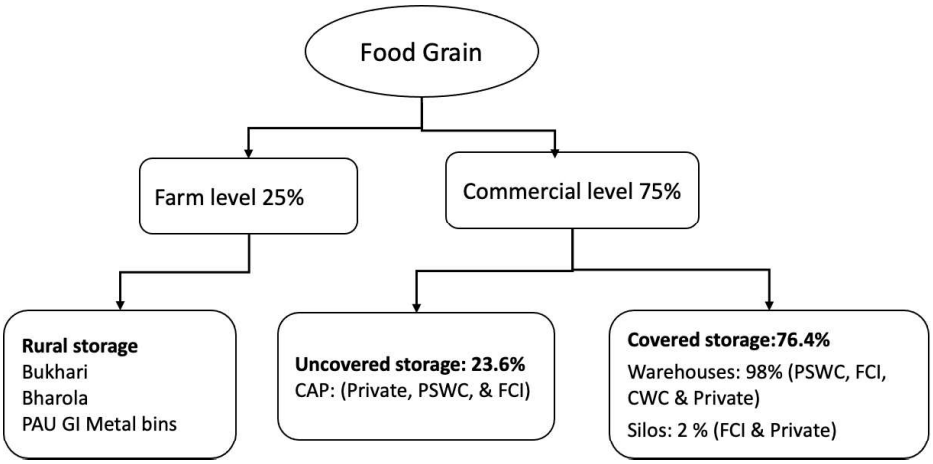

Fig. 1. Status of food grain storage in Punjab.

There are three different categories of storage structures (temporary, semi-permanent, and permanent) available in the state for storage of produced food grains. The classification of structures is done based on the duration of storage, types, design, and utility. The storage structures used at farm level and CAP fall in the category of temporary to semi-permanent, and the warehouse or silos structures fall under the category of permanent structures.

Covered type storage

The storage of food grains under protected structures (with partial or full control of environment) is called covered storage. Types of covered storages used for grain are warehouses, bins, and silos which all fall under the permanent storage category. These structures are managed by three different agencies: Punjab State Warehousing Corporation (PSWC), Central Warehousing Corporation (CWC), and Food Corporation of India (FCI).

The PSWC is one of the oldest state warehousing corporations in the country and has 120 operational warehousing centres across the state, including 133 owned and 348 hired warehouses, equivalent to the storage capacity of 5.5 Mt (Anonymous, 2021). Despite having these large storage facilities, demand for storage is not met in most years; therefore, temporary CAP storages are also created to supplement the capacity. A majority of the warehouses (5,000-50,000 tonnes) in Punjab and in most Indian states are still managed by an unorganized sector and only about 7–8% of modern warehouses have adequate size, racking systems, palletization and standardization, and out of the total warehousing space, almost 82% is not mechanized (Gurpreet and Chaudhary, 2014). All warehouses present in the state are based on old designs and standards because the establishment and management of warehouses had been done by government agencies like CWC, SWC and FCI in the 1960s (Fig. 2).

Fig. 2. Types of conventional warehouses (top and middle left); Modified single span with common road loading-unloading and with rail loading-unloading (top right); Dome shaped single span (bottom left); Gable shape single span (bottom right).

The overall size of a 5000-tonne godown is 130.6 m length x 21.67 m width x 5.4 m height with plinth height of 0.6 to 0.8 m, which can accommodate 12 bag stacks in each occupying area of 6.10 m x 9.14 m. The ventilation of godowns (2% of covered area) is carried out by windows, wall ventilators, and rolling doors of Size; 0.60 m x 0.60 m, 1.50 m x 0.60 m, and 1.83 m x 2.44 m, respectively (Anonymous, 1962).

Under the Jute Packaging Materials (JMMA) Act, 1987, it is mandatory to use jute bags as the packaging material for the storage and transportation of food grain in India. Therefore, jute bag storage is a very common form of storage used in these warehouses (godowns) and their layouts and management is done as per standards (Fig. 3). The grain is stored at a recommended safe moisture level, generally of less than 14% for long term storage for wheat. The standard dimension recommended for each bag (50 kg) stack is 9.14 m x 6.09 m x 4.5 m. The minimum gap of 0.75 m between two stacks, 0.8 m between walls and stack, and 1.5 m between top of stack and roof is used. Storage in bags offers many advantages like easy movement and handling by unskilled labour, ease of fumigation, ease of sampling, reusability of bags, and good mechanical properties. There are some disadvantages like grain spillage during improper handling, prone to rodents and insect attack, fluctuation of grain moisture due to atmospheric moisture absorption or drying, and easy infection by mould.

Fig. 3. Stack arrangement of food grain bags inside a conventional warehouse: lengthwise (left); and widthwise (right).

Silos require about 1/3 of the land as compared to existing conventional warehouses (1.75 acres) and offer many advantages over conventional warehouse storage like mechanized handling and efficient storage management. Therefore, PSWC and FCI have constructed steel silos of 0.15 Mt and 0.2 Mt capacity (2% of present covered storage capacity), respectively under Public Private Partnership (PPP) mode in Punjab to modernize the storage infrastructure and improve the shelf-life of stored food grains (Fig. 4). Constructed silos offer numerous advantages such as reduction of post-harvest losses and savings on gunny bags, wooden crates, tarpaulin covers, and labour wages. It forms an integrated supply chain and logistics model that procures food grains from farmers and local mandis, and supplies to the Public Distribution System (PDS) in Punjab. The losses caused by rodents, insects, fungi, and handling in a silo system is about 0.2% compared to 8% in a godown system (Sawant, 1985).

Uncovered storage

Present infrastructure for grain storage in Punjab does not meet the demand of buffer storage of food grains, thus uncovered storages have been used. Although grain in such structures is highly prone to damage by biotic and abiotic factors, agencies prefer their use for short term storage to bridge the gap between supply and demand. The CAP storage is a type of uncovered storage in which grains are stored in an open space on wooden dunnage over rat and moisture proof raised plinths, and then the stacks are covered by 250-micron LDPE sheets from the top and along the four sides (Fig. 5). FCI and PSWC has 3.44 Mt of owned and leased CAP storage capacity at present in Punjab, which constitutes about 23% of total storage capacity. Weather is the major grain damaging factor, which can cause huge post-harvest losses during bad weather like heavy rains and higher humidity.

Fig. 4. Modern silo facility at Moga, Punjab.

Fig. 5. Cover and Plinth (CAP) storage of food grains.

For safe and proper storage under Indian conditions, research is required for quality management for local climatic conditions with careful selection of the storage site, storage structure, implementation of Integrated Pest Management (IPM), and with proper aeration of grains followed by regular inspection of grain stock (Sharon et al., 2014).

Rural farm storage

This is another form of temporary type, uncovered or partially protected form of storage found in rural Punjab. Punjab is an agrarian state, and therefore most of the farmers produce and store their

food grains at farms for their own consumption and seed purposes after selling surplus grains. They use locally available raw materials to develop traditional structures which are different in design, shape, size, and capacity (Dhaliwal and Singh, 2010; Fig. 6). Singh (2002) evaluated post-harvest losses in these storages of Punjab and found that about 94% of food grain could be lost due to damage by biotic and abiotic factors.

Major insects and management

The common classification of the storage insects is based on their feeding habit as primary pests (generally internal feeders) and secondary pests (external feeders). Common insects found in stored grain in Punjab are: Rice weevil, *Sitophilus oryzae* (L.); Wheat weevil*, S. granarius* (L.); Lesser grain borer, *Rhyzopertha dominica* (F.); Saw-toothed grain beetle, *Oryzaephilus surinamenis* (L.); Flat grain beetle, *Laemophloeus pusilloides;* Khapra beetle, *Trogoderma granarium;* Rice moth, *Corcyra cephalonica* (Stainton); and Paddy moth, *Sitotroga cerealella* (Olivier). These insects thrive in stored grain and can live 25 to 300 days (Tyagi et al., 2019).

Fig. 6. Farm level small scale storage structures: Kupp (left), Bharola (middle), and PAU Bin (right).

Chemical management

About 90% of food grains are stored in conventional godowns (warehouses) in Punjab, therefore the most used preventive and curative method is chemical treatment. These methods are popular for insect management in private mandis, PSWC, and FCI warehouses because they are inexpensive, easily accessible and can be managed by unskilled workers. Fumigant is a chemical with higher vapour pressure, is toxic to insects and is able to penetrate through the commodity. Unlike chemical sprays, fumigants require airtight conditions to achieve full efficacy. Relative humidity and temperature in storage, as well as the moisture content of seeds and air tightness were important factors influencing the efficiency of fumigation.

Presently, aluminum phosphide (ALP) is the formulation available in India for large scale fumigation to control stored product pests effectively. It is the first line of defence in grain storages of Punjab, and generally recommended at 3 tablets per tonne of food grains (each tablet is 3 g and can release 1 g of phosphine gas).The fumigation period is 7 d. Wherever *Trogoderma* larvae are present then doses may be raised by 50%. The detailed applications, dosages and schedules are given in Tables 1 and 2.

Table 1. Prophylactic treatment to stacks/godowns for disinfestation of food grains in Punjab

Chemical	Dilution	Dosage of prepared solution	Remarks
Malathion 50EC	1:100	3/100 m^2	Spray on stack surface on in 15 d
		1L/270 m^3	For aerial spray once a week or as the situation warrants
Deltamethrin 2.5WP	40 g/L	3 L/100 m^2	Spray on stack surface once in 90 d
DDVP 100EC	1:150	3 L/100 m^2	To be sprayed only 20% for godown disinfestation. Not to be sprayed on food grain bags

(Source: FCI Quality Control Handbook, 2018)

Table 2. Pest control plan in storage by Food Safety and Standards Authority of India

Schedule	Frequency	Treatment	Area
Daily	Three times	Integrated fly management	In and around building, entry points (doors and shutters) and breeding grounds
	Four times	Electric flying insect control	Food grain godown, bran collection, coding room, packing room
	Once	Rodent check	Near storage zone
Weekly	Once	Non-selective disinfestation	In and around building, entry points (doors and shutters) and breeding grounds
	Once	Lizard management	Outside storage area
Fortnightly (Mar – Oct)	Once	Prophylactic sprays	Crawling insects
Monthly (Nov - Feb)	Once	Prophylactic sprays	Insect hiding places
Monthly	Once	Cockroach management	Cracks and crevices
45 d (need based)	Once/as and when required	Fumigation	Grain, equipment and others

(Source: Food Industry Guide 2017)

Table 3. Commercially available products based on botanical pesticides

Active Ingredient	Dose (ml per litre of water)
Oil of neem (*Azadirachtin*)	5.0 to 10.0
Essential oil of garlic (*Allium sativum* L.)	5.0
Citrus cinensis L. oil (limonene and linalool)	2.0 to 5.0
EO of thyme (*Thymus vulgaris*)	2.0 to 5.0
Rotenone	5.0
Nicotine (*Nicotiana tabacum* L.)	10.0

(Source: Guru P.N. and Mridula D. 2021)

Use of plant derivatives for stored product protection is an age-old practice and still in use under rural farm storages of Punjab. Because of the active ingredients present in them, botanicals help in managing insects through several actions as: repellents, antifeedants, toxicants, chemosterilants, and growth regulators. Plant families like meliaceae, myrtaceae, apiaceae, lamiaceae, lauraceae, poaceae, and pinaceae are reported to contain insecticidal secondary metabolites/volatiles like terpenoids, alkaloids, and phenolics. The dosages range from 2 to 15 g/kg of food grains; however, sometimes use can be >20 g/kg. The active stages, especially those of adult insects, are generally more susceptible than eggs. Botanical neem kernel powder at 2% (w/w) was found to be effective against S. oryzae on stored wheat in Punjab with no significant adverse effect on seed germination (Singh et al., 2017). Commercially available products are given in Table 3, which are being used by farmers at their farms for grains stored in metal bins.

Conclusions

The network of covered conventional godowns and uncovered CAP storages, along with rural farm structures, has been playing an important role in Punjab's grain storage and India's national food security. Presently, insect management in commercial storage is largely relying on earlier developed storage protocols and fumigation by Aluminum Phosphide, Malathion, and Deltamethrin. The research on abiotic and biotic factors, physical methods, and stored product entomology in grain storage of Punjab is meagre, which limits the insect management and results in significant use of chemical fumigants and insecticides. Improved versions of rural farm structures with standardized plant-based formulations have the potential to reduce post-harvest losses and ensure local food security in rural areas. Timely repair and maintenance of structures, frequent monitoring of grain, aeration, personnel training, and shifting from uncovered to covered storage are all important measures that can be implemented in both the organized and un-organized sectors which are involved in grain handling and storage for enhancing safe storage capacity and reducing post-harvest losses.

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