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Strategies and Techniques for Safe Storage of Food Grains and Scientific Methodologies to Reduce the Post Harvest Losses

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Every year, approximately two billion tonnes of grains are produced throughout the world. Grain is kept in specified units such as sacks, silos, warehouses, containers, and even heaps on the ground at various points of the grain distribution chain. Post-harvest losses of grains are difficult to quantify accurately, although they can range from 1–2% in affluent nations where grain is kept in well-controlled facilities to 20–50 per cent in less developed areas with poorly managed storage systems. Approximately 60-70 percent of India's population is involved in agriculture in some way. Because of various methodological restrictions and the requirement for experienced staff, assessing storage loss (quantitative and qualitative) is a challenging task. Infestation diagnoses are necessary stages in determining the proper identification of the insects, as the harmful symptoms differ by species. Thus, there is an urgent need to integrate current information to give recommendations for future research and development in order to reduce grain post-harvest losses in various parts of the world.

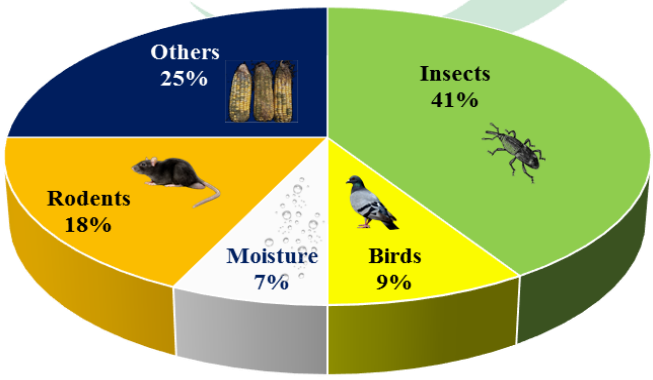

Fig 1: Post harvest losses caused by different factors

(Open source: TNAU Agritech portal)

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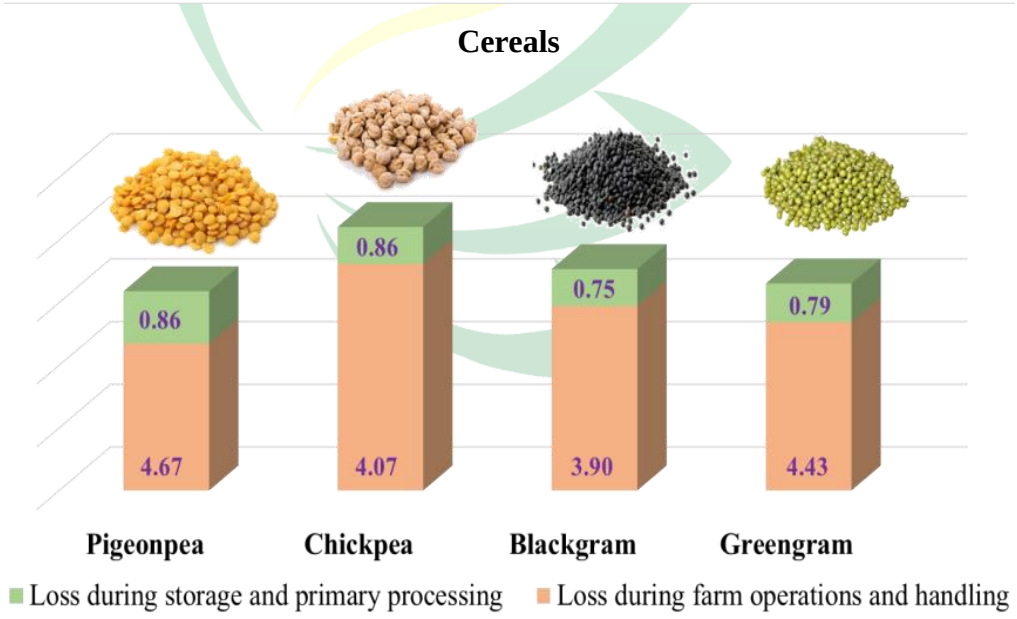
Indian Council of Agricultural Research (ICAR-Central Institute of Post-Harvest Engineering and Technology (CIPHET) conducted studies on 'Assessment of Quantitative Harvest and Post-Harvest Losses of Major Crops and Commodities in India (Jha et al., 2015). According to this report, losses of food grains were higher during harvesting, threshing and storage at farm and wholesaler level. In monetary terms, it was estimated that the losses were about Rs. 92.65 thousand crores (as per market value 2020).

From season to season, whenever the supply reduces year by year the surplus stored produce must be used into the market to survive in these lean seasons. The proper and timely release of the surplus food will balance the market price and will preserve the country's economy.

Cereals



Pulses

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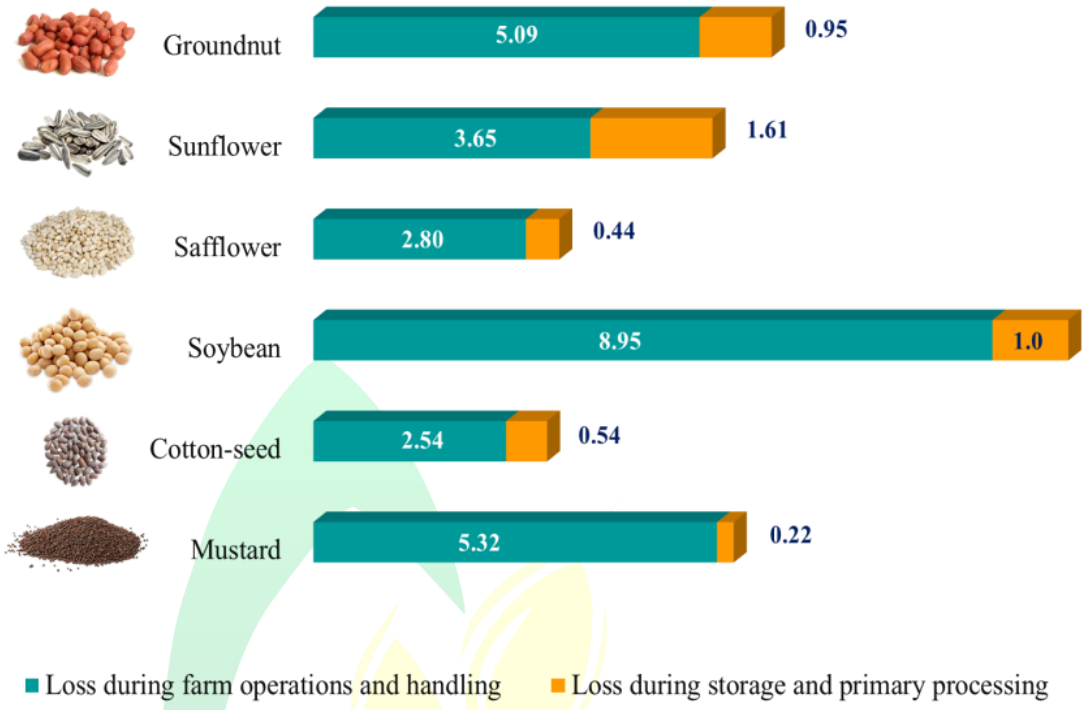

Fig 2: Commodity wise harvest and post-harvest losses at national level (Jha et al., 2015)

In India, storage is done at three different levels: (i) farmer level, (ii) trader level and (iii) commercial level. At farm level, farmers store crops to satisfy the household's needs during the off-season; specifically, for their family and to utilise it as an asset for cash or barter exchange as well as seeds. At the trader level, storage is normally done for a relatively short period of time, ranging from a few days to a few weeks. The traders' storage time is generally determined by the market price. At the commercial level, any organisations, millers and co-operatives keep food stock for a period of time till they can meet the demands of their clients/ stakeholders.

For safer storage of different grains, grain moisture is an important parameter to be taken care of. The longer the grain needs to be stored, the lower the moisture content required. Maintaining a moisture level of 10-12 % in cereals and 7-9 % in oil seeds (on wet basis) can effectively store the food grains for about 6-12 months. However, the moisture content at harvesting is different for different crops i.e. 20-22% for rice, 20% for wheat, 14% for maize and 9% for pulses. Stacking of bags is also an important factor for safe storage. For example, rice requires a bag stacking height of 4.27 meters (16 layers) while it is 4.57 meters (18 layers) for wheat grains.

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Table 1: Moisture content requirement for safe storage of grains below 27°C and 70% RH (IGMRI, Hapur)

Crop	EMC
Maize shelled	13.5
Maize flour	11.5
Wheat	13.5
Wheat flour	12.0
Sorghum	13.5
Millet	16.0
Paddy	15.0
Rice	13.0
Pulses	15.0
Lentil, pea	14.0
Groundnut (shelled)	7.0

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Figure 2: Types of conventional warehouses top & middle-left: Modified single span with common road loading-unloading; bottom-left: Dome shaped single span; top-right: Modified single span (Gable shape) with rail loading-unloading; bottom-right: Single span

Limiting Factors for the safe storage of food grains

Several causes such as insect pests, microorganisms, rodents, and birds, are responsible for the quantitative and qualitative deterioration of food grains during storage, reducing the food grain's shelf life. Therefore, we must pay attention to many variables such as the nature of the storage structure, the type of commodity kept, the period of storage, and the quantity of food grain stored, as well as climatic conditions, in order to keep the food grains safe during storage. In general, commodities that are kept for a long period are more susceptible to biotic and abiotic contamination and destruction. Among the biotic agents, insects, mites, rodents, birds and micro-organisms cause immense loss in storage and the major damage is mainly caused by insects. A substantial damage can be done by various abiotic factors, if they are not in optimum magnitudes as required for the safe storage of the commodities. It includes temperature, grain moisture, relative humidity and storage time which also play an important role in grain storage.

Although different management practices have been adopted from traditional times for minimizing the storage losses, yet, here are some of the important management tactics that should be used to maximize the efficiency of safe storage of different agricultural commodities

Storage pest management

The storage pest management is mainly concentrating on the management of the insects, micro-organisms, rodents and birds, as these are the organisms contributing for the major storage losses. Different preventive and curative measures can be adopted to minimize these losses.

Preventive measures

- Harvest at the right time, when grain moisture levels are low enough to avoid grain damage while handling.
- After harvesting, proper washing and scientific drying of the grains, with minimal kernel or seed damage caused by harvesting machinery.

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- Cleanliness of the storage structure. Clean the grains thoroughly, avoiding the accumulation of foreign matter and dirt on the grains.
- Separate the broken kernels from the seeds by grading them.
- Keep an eye on the field inoculum and take the required steps to avoid the population explosion before storing it.
- A thorough inspection of the storage area, as well as sampling to detect any infestations, is required and should be done on a regular basis.

Curative measures

- **Hermetic storage**: It is defined as controlled aeration where the O_2 concentration is reduced while CO_2 concentration is elevated, thus, affecting the metabolic activity of the insects. Maintaining the exposure of depleted O_2 (< 3%) and elevated CO_2 (> 50%) for more than 24 h, significantly distress the insects. Recently, bags or structures fabricated with layered high-density polyethylene (HDPE) were proved efficient in insect control by lowering oxygen concentration in smaller trials.
- **Low-pressure storage**: Designing structures for decreasing the pressure is another area of development in storage. This is one of the methods for causing insect death by hypoxia and dehydration.
- **Temperature control**: In general, even a minor variation in temperature has a significant impact on insect growth and development. Grain disinfestation using thermal treatments was traditionally done in a controlled environment with hot/cold air/water.
- **Other physical treatments**: include inert dusts such as Silicon dioxide (SiO2) and Diatomaceous Earth (DE), which have been proven to be effective against stored-grain insect pests. Ionising radiations, such as gamma rays, x-rays, or electric beams, have lately been used in stored-grain disinfestations, resulting in insect sterilisation, death, mutations, and deformities.
- **Plant derivatives**: Because of the active compounds contained in botanicals, they have been claimed to control insects in a variety of ways, such as repellents, anti-feedants, toxicants, chemo-sterilants, growth regulators, and so on.
- **Biological control**: Predators, parasitoids, and diseases were thought to be the most environmentally beneficial and sustainable management options. Some commercially

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available entomopathogenic fungi, such as *Beauveria bassiana*, *Metarhizium anisopliae*, and the bacterium *Bacillus thuringiensis* (*Bt*), were also tested against various stored-grain pests, particularly beetles. Grain moths were effectively controlled by *Habrobracon hebetor* (Say), whereas Pulse beetles using *Dinarmus basalis* (Rondani) and *Pteromalus cerealelle* (Boucek).

- **Chemical methods**: There are a number of ready-to-use sources on chemical protectants for grains and storage buildings (NSPM-22, 11, 12, 15). The effectiveness of fumigation is influenced by relative humidity and temperature in storage, seed moisture content, and air tightness. Aluminium phosphide (ALP) is already available for large-scale fumigation to successfully manage stored crop pests. 3 tablets per tonne of food grains is often suggested (each tablet is 3g and can release 1g of phosphine gas). The fumigation should last for 7 days. Wherever *Trogoderma* larvae are found, the dosages should be increased by 50%. (FCI).

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	3L/100 m^2	Spray on stack surface once in 15 days
		1 L/270 m^3	For Ariel spray once in a week or as the situation warrants
Deltamethrin 2.5WP	40 g/L	3 L/100 m^2	Spray on stack surface once in three months
DDVP 100EC (restricted after 2020)	1:150	3 L/100 m^2	To be sprayed only 20% for godown disinfestation. Not to be sprayed on food grain bags.

(Open source: FCI Quality Control Manual, 2018)

Prophylactic treatment	**Curative treatment**

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To prevent the insect infestation and cross infestation. However insecticide should not be sprayed on food grain directly	Mixing of chemicals with food grains meant for human consumption is not recommended. However they can be mixed with grains meant for seed purpose only. Normally pyrethrum dust is used as seed protectant
Malathion 50 E C at 0.5%	Fumigation is the best method for controlling stored insects.
	Aluminium phosphide @ 9g/tonne of grains. The available formulations are tablets and powder pouches.

Fungal management under storage

- Fungi can survive and proliferate in a wide range of temperatures. Although, temperatures below 20°C and over 40°C, along with dry conditions, will inhibit colonisation.
- Whole grains and sound grains are more resistant to illness than broken grains contaminated with foreign pollutants. As a result, the first and most crucial step is to clean.
- Care should be given while storing grains for an extended period of time, since the initial inoculum in the grains may grow at a later stage. Similarly, lengthy periods of undisturbed circumstances foster the development of pests in the stacks.
- New lots should be stacked separately and the isolation gap between stacks should be maintained.
- The insects and mites are the vectors of microbes, they carry the spores, creating the congenial condition for the fungal growth. Although primary damage is done by the insects the secondary decay will be faster once the microbial association is established.
- The seed borne pathogen can be treated by dry heat at 65˚C for 6 days or dipping in hot water treatment at 52–55˚C. Seeds can also be treatment with fungicides such as Dithane M-45 and Benlate at the rate of 3g per kg.

Rodent management

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- Rodent pest control includes the use of rat barriers, rat cage traps, and rodenticides. For the control of rats in warehouses, single dose acute rat poisons such as Zinc phosphide, Barium carbonate, Red squill, ANTU, and single dose anti-coagulants such as Bromadiolone and Brodifacoum may be used in the dosage indicated.
- In surrounding farms and open spaces, rat burrows can be fumigated with 0.6 gm Aluminium Phosphide pallets. Burrow fumigation can also be done with 10 gm sachets of aluminium phosphide.

Bird management

- Important preventative measures include scientific grain management and minimising spillage.
- Bird scarers, such as metallic sheets and ribbons, can be used.
- Acoustic device (Bird scarer/acetylene exploder): emits a loud, abrupt sound that scares birds. Firecrackers can also be used to scare away squirrels, rats, mice, and other small animals.
- Slow-drying plastic jellies can be sprayed to sedges where birds perch. The perching bird feels insecure as a result of this.
- Rodents and cats may also be considered natural predators within stores due to ultrasonic disruptions and recorded bird calls (warning cries and distress calls).

Storage pest management plan

For storage at large scale

- Sun drying/scientific drying of grains to maintain optimum grain moisture content
- Plastering of storage bins with clay/cow dung/cracks should be filled with cement
- Regular monitoring for pest infestation using probes/visual count. Sanitation and regular fumigation of godowns/store rooms
- Use of methyl anthranilate as a bird repellent; application of chlorpyriphos/ imidacloprid for termite control; rejection and isolation of old stacks; and separate stacking of new lots
- Spraying godowns with deltamethrin @ 20-25 mg/sq. m area or cypermethrin @ 30-50 mg/sq. m area
- Insect proof bagging for avoiding infestation
- Trapping using Box trap, back break trap and wonder traps for rodent control

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For storage at domestic level

- Use Pitfall traps to check insect infestations on a regular basis
- Use ash, red soil or clay, common salt, and chilli powder for grain storage