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Post-harvest techniques for quality seed production: An approach

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Abstract
As a recent period's demanding enterprise, there is always a need for healthy seeds in order to provide a good yield in the next season. In order to preserve a crop with a high yield, seeds must be stored. Numerous biological and non-biological processes cause significant losses of seeds during storage. Examining the causes of these crop losses is necessary since they eventually affect the market price and seed quality. Careful postharvest handling practises can help preserve the quality of seeds. In order to minimise loss and maintain the quality and safety of the crop, it is necessary to design the most appropriate procedures for assessing losses that occur during the process. The goal is to produce high-quality seeds that fulfil both national and international standards and might satisfy the supplier's needs. The postharvest practises and factors that are employed to preserve seed quality are highlighted in this paper. A thorough analysis of the more effective, affordable, practical, and productive ways is given; it is centred on the requirements of developing nations.

Keywords: Post-harvest, techniques, seed, quality, production, storage, drying

Introduction

Good and healthy harvests start with high-quality seeds. The supply and quality of seeds still need to be improved. In the vegetable and flower seed industries, in particular, scientific and technical proficiency in crop enhancement, in the areas of production, processing, and usage, has improved. To ensure there is enough food for all people, it is crucial to find and create superior agricultural crop seeds that can withstand heat, cold, disease, drought, and insect pest attacks. Farmers can now grow a wide range of resilient food and fibre crops that were unheard of just a few years ago thanks to the seeds currently in use (Tiwari, 2020) [1].

It takes more time and money to grow a crop for seed production than it does to grow a crop for grain. Maintaining the genetic and physical purity of the seed should be given first importa nce when beginning seed production (Mann *et al*., 2016) [2].

Better seed quality and post-harvest storage methods are what allow the seed industry to continue to exist. A high achievement and quality assurance are sought after by this seed quality programme. One of the most demanding industries in the modern era is seed quality. The bulk of small-scale farmers' seeds, particularly those for cereals and legumes, are grown and kept on the farms. By using efficient storage strategies, the main issue, damage caused by biological elements like insects and molds can be reduced (Woodstock, 1966) [3]. The prevention of crop losses and the storage of seeds and grains is the top priority of farmers. Due to the risk of crop loss, farmers frequently buy new seeds or grains from the market to create the next harvest for a higher yield. The development of efficient seed storage methods that can confirm improved crop yields and lower the likelihood of storage losses is required (Gregg and Billups, 2010) [4].

The value of the seeds enables farmers to grow high-yielding crops from healthy and high-quality seeds. The ability of a seed to produce desirable quality, healthy, and high-yielding crops at low planting rates is referred to as seed quality (Gregg and Billups, 2010) [4]. Seed quality cannot be achieved automatically or through an ongoing process. The quality of the seeds is under strain from the environment. To provide farmers with the highest quality seeds, efforts are being made. Any stage of handling or production has the potential to degrade the seed's quality. All seed activities must be managed technically carefully in order to reduce these losses (Boxall *et al*., 2002) [5].

Objectives of seed processing

Seed processing is done to improve the seed quality by removing foreign objects, inert materials, small seeds, weed seeds, deteriorated and damaged seeds, and by providing chemical protectants to the seed to improve its planting circumstances. As a result, seed processing is crucial to:

- Enable uniform planting through correct size and the removal of seed appendages that obstruct planting.
- Boost seed marketing by enhancing product quality and preserving dependable seed-planting standards.
- Remove weed seed from crop seed to stop the spread of weeds.
- By eliminating contaminated seed from clean seed, you can improve crop quality.
- Use chemical treatments to protect crops from pests and illnesses.
- Reduce seed losses by drying seeds and reducing moisture content.
- By providing storage from the time of harvest until the seed is required for planting, you can promote uniform marketing.

Postharvest techniques of seed storage

1. Drying

Cereal and legumes reach physiological maturity at moisture contents between 35 and 45 percent, depending on the crop. When seeds have a moisture level between 10% and 14%, temperature has an impact on how long they can be stored. Timely harvesting and drying of crops are essential for a high-quality yield. In most cases, fungal infection and insect and other pest attacks cause biologically active seeds to degenerate quickly. Reduced respiration in seeds is the primary goal of drying (Boxall *et al*., 2002 & Kiaya, 2014) [5, 6]. The procedure also prevents quality loss brought on by pest insects and other fungus. The process of drying itself may have an impact on the seeds' quality. The seed may suffer if it is dried extensively at a high temperature. Simple drying techniques are utilised in the summer by exposing clothing to the sun and getting enough wind. To deal with higher output or harvesting during the wet season in multi-cropping, different drying methods have been developed for high-yielding varieties and enhanced agricultural practises and irrigation (López *et al*., 2010 & Mujumdar and Law, 2010) [7,8].

2. Sun-drying

In emerging tropical nations, seeds are typically dried by sun exposure. When the crop is ready for harvest, the procedure is used. Some seeds, like maize, can be sun dried, but crops become more susceptible to pest attacks like insects, rodents, and birds, as well as mould damage, throughout the drying process. Although it is a typical occurrence, spreading threshed seed to dry on sheets or a tray runs the danger of contaminating it with dirt or stones. For instance, paddy is available in big quantities at rice mills (Boxall *et al*., 2002) [5]. On specially constructed drying floors that make it simple for rainwater to drain off, rice is dried. To aid in drying, the seeds are spread out in thin layers, flipped at regular intervals, and covered at night with sheets. The technique has some drawbacks because temperature is an unpredictable variable. High temperatures in paddy rice can stress or break the seeds, which results in significant damage during milling. Dust, air pollution, insect infestation, and human or animal disturbance are all potential sources of yield contamination (Boxall *et al*., 2002 & Kiaya, 2014) [5,6].

3. Solar drying

It is a version of solar drying in which solar rays are gathered in a unit created especially for the removal of air in a sufficient ventilation system. The device uses less time and has a temperature that is 20–30° greater than open drying (Chen and Mujumdaer, 2008) [9]. In solar dryers, air is heated using solar collectors and then let to travel to the seed beds. It has two fundamental designs: forced convection dryers force air through solar collectors and seed layers, while natural convection dryers exploit thermal gradients. These dryers are appropriate for use on farms. The old design of the Asian Institute of Technology in Bangkok, which consists of a drying bin, a solar chimney, and a solar collector, has formed the basis for other convection dryers (Boothumjinda *et al*., 1983) [10]. The solar collector is made of a layer of burned rice husk or a black polythene sheet and is covered with a clear polythene sheet. In the drying bin is a pedestal with holes in it. The following are the procedure' drawbacks: a high structural profile, stability issues in windy conditions, and the requirement for routine replacement of polythene sheets (Boxall *et al*., 2002) [5].

3.1 Mechanical dryers

Mechanical dryers use the same drying technique as forced convection solar dryers; the air is forced through the seed bed and heated with the aid of a flat plate as opposed to conventional methods. Drying occurs at one of two points in a modern automated storage system: either in prestorage dryers (before seeds are loaded into freestanding loading containers) or in store dryers (after seeds are loaded into the final storage compartment) (Kiaya, 2014) [6]. Continuous flow dryers used in prestorage dryers employ ambient air, and a thermostatically regulated furnace, powered by electricity, diesel, or gas, produces heat. Heat can be delivered directly or indirectly. Because the combustion product has a separate outlet and does not go through seeds, the indirect method is recommended. While grains are flown into the system and collected at the correct moisture level in continuous flow dryers, seeds are supplied into properly defined batches in batch dryers (Boxall *et al*., 2002) [5].

3.2 Tray dryers

Batch dryers having flat beds called tray dryers. To thoroughly dry the seeds, they are spread out on the mesh tray at a depth of 600–700 mm. Warm, dried air is then pushed through the seeds (Boxall *et al*., 2002 & Kitinoja and Gorny, 1999) [5, 11].

4. Radial drying bins

Two vertical metal mesh cylinders with one within the other make up the radial drying bin. Between these two cylinders, seeds are loaded, and air is forced into the inner cylinder and transferred from the inner to the outer mesh cylinder. You can remove air from the central cylinder by forcing air through seeds in the opposite direction. Seeds in the inner cylinder that are in direct contact with the hot air run the danger of being over dried. At the exit side, near the outside, the air is cooler and wetter (Boxall *et al*., 2002) [5].

5. Continuous flow dryers

The moisture content of the seeds can be reduced by sucking or blowing hot air through the system from top to bottom. A bin and cooling system are located at the bottom of the drying portion. Seed beds can be vertical, sloping, or horizontal.

Conveyors, scrapers, vibration, or gravity are used to transfer seeds. The speed, size, and rate of flow of the dryer's outlet belt all affect how much moisture is removed. The relative orientation of the air stream and seed flow alters the continuous flow dryer (Radajewski *et al*., 1987) [12]. Below are descriptions of several continuous flow dry processes.

5.1 Cross flow

The two perforated sheets allow air to move horizontally through the seeds, allowing the seed to pass through and into the column. The dryer's advantage is that the moisture gradient can be established at any point during the drying of seeds (Boxall *et al*., 2002) [5]. Cross-flow dryers have been employed extensively recently.

5.2 Counter flow

Seeds are discharged from a spherical bin using an upward airflow. Even when the hottest air flows through the driest seeds, little evaporative cooling occurs.

5.3 Concurrent flow

When air is moving through a seed bed concurrently, the wettest seeds are exposed to the warmest air. High temperatures increase drier efficiency and chill the seeds by evaporating moisture (Heid, 1980) [13].

5.4 Mixed flow

Mixed-flow dryers have advantages over cross-flow dryers. The combination of contemporaneous, counter, and cross flow dryers in mixed flow dryers offers the major advantage of efficient fuel use. The largest obstacle to the adoption of mixed flow drying, however, is the decrease in yield caused by uneven seed flow, which causes uneven drying (Boxall *et al*., 2002) [5].

5.5. Mixed flow tower

They are made up of tall rectangular storage bins, and horizontal triangle ducts run the length of the dryer's breadth. The remaining ducts are used to remove dampened and cooled air, while half of the ducts are utilised to introduce warm air. It has several air and seed flow directions (Heid, 1980) [13].

5.6 Fluidized bed dryer

The seeds are dried by hot air that is blown over them after passing through several types of batches. The cross-flow dryer theory underlies how the dryers operate. The degree of drying determines the speed and depth of the drying beds. Conveyor dryers and cascade dryers are the two primary dryer designs. Cross-flow dryers with gravity feeding are the cascade dryers. Roller dams control the seed depth, while output elevators control the speed. Changes can be made to the dryer's design to alter its length. In a conveyor drier, air is forced onto the seeds through an inclined fliudized bed, with heavy duty, roller chain, and variable speed conveyors controlling the seed flow. These dryers can be unidirectional, bidirectional, or multidirectional; the directional change helps with waste material removal and dryer size reduction (Boxall *et al*., 2002) [5].

6. Store-based or in store drying

In this alternative drying procedure, seeds are loaded into bins or bulk floor storage before being dried in stores (Chung, 1986) [14].

6.1. Large-scale floor storage

They are made with particularly reinforced walls that can support the weight of seeds. The seeds are stacked at a constant depth. The plenum chamber runs in the middle of the store or walls with perforated lateral ducts, below or above the floor level under the majority of seeds, and the fan is located at one side of the building for aeration purposes (Boxall *et al*., 2002) [5].

6.2 Bin drying

One or more bins are used for drying, and other bins are used for storage in this form of drying. Due of the decreased handling, dryers decrease the possibility of physical harm. The drying process is faster and safer thanks to the shallow layer of seed around the bins. The semi-dried batches, which consist of ventilated floors or lateral ventilation systems around 0.5 m above the base (Bartosik, 2005) [15], free up room for incoming seeds.

6.3 Bag dryers

It is challenging to dry seeds in bags because there is inadequate protection against air passing through the seeds. In fan blowers, hot air is blown from the floor apertures and sacks are put on them, as opposed to sack platform dryers, which blow air through the air duct's floor. In the moisture extraction unit, larger bags are placed in the middle of the tunnel. Hot air is circulated through the air ducts with the aid of a fan. To prevent uneven drying, proper dimensioning must be observed. However, because of short circuits in some places, this technique is not suitable for even drying seeds (Boxall *et al*., 2002) [5].

Storage losses

According to reports, harvest-related agricultural losses amount to a total of 30%. However, this is the "worst case" estimate to use for the crops in the development priority area. Before harvest, storage losses cannot be estimated. Crop losses can result from a variety of biological, climatic, handling, harvesting, storing, and distribution, as well as social and cultural reasons (Yousaf *et al*., 2016) [16]. 50 percent of post-harvest and storage losses can be distributed with appropriate handling. There is no way to determine the precise sum of such damages. There has been work done to identify the trustworthy baseline techniques for calculating crop loss activities. To calculate the standardised post-harvest losses for different crop operations, a methodology has been developed (Harris and Lindblad, 1978) [17]. The Food and Agricultural Organization (FAO) of the United Nations has encouraged loss assessment and loss reduction programmes. The goal of these projects was to prevent the decline of staple food crop production. Even though there was no set approach for evaluating storage losses, the methodology for assessing seed loss during harvest was summarised (Boxall, 1986) [18]. The loss assessment phenomenon is non-generalizable, particularly for perishable commodities, due to sampling methodologies, different handling and storage products, and irregular batch movement. An acceptable, cost-effective, and relevant technique should be carefully designed with positive goals in mind. Due to their distinct nature, perishable goods require a variety of procedures, whereas grain seeds require rather standard methods. It is possible to compare the weight loss of undamaged and damaged seeds in order to determine standard moisture content and dry matter. Storage is used to prevent yield losses on a biological and economical level. We needed to be aware of what was causing these losses in order to prevent them (Kiaya, 2014) [6].

1. Damage and loss

Damage and loss are sometimes used interchangeably, which can be confusing. Loss is defined as a quantifiable drop in the quality or quantity of food. The term "superficial deprivation of commodities" refers to damage where physical decay causes loss of the product. Although a damaged good can still be used, a loss represents a permanent deterioration. (Mohammed, 2014) [19].

2. Classification of storage losses

The stored seeds are directly impacted by the main cause of losses. Economic effects can be attributed to qualitative or quantitative storage loss categories. Physical weight or volume loss, which is regarded as a quantitative loss, is easily calculable. By judging a commodity and comparing it to goods of similar quality, one can estimate quality losses. Changes in flavour, texture, appearance, nutritional value loss, and the presence of pollutants can all cause consumers to reject a commodity. To illustrate the agricultural storage losses, the following categories can be listed (Boxall, 2002) [5]: They could have a biological, chemical and biochemical in nature.

2.1. Natural catastrophes or biological losses

Rodents, insects, birds, and microorganisms (fungi and bacteria) are biological causes that cause crop deprivation. Crop weight loss, crop rotting, and other faults brought on by microbe growth on the crops lower the market demand for the produce. If produce is kept in storage for an extended amount of time, infestation development may become a problem. Birds, rodents, and microbiological (fungi and bacteria) attack in the field can worsen storage conditions and cause more severe damage or loss to wheat seeds. If the disease is only superficial, there will be a quality loss; if it spreads deeper into the seed layers, there may be a quantity loss. It is feasible to employ the remaining portion of the affected area when a superficial disease is present (Kader, 2002) [20]. Chemical losses result from pesticides and chemical interactions and include flavour, colour, texture, and nutritional value loss (Atanda, 2011) [21]. Due to enzyme-activated processes, biochemical losses can include softening, discolouration, and unpleasant flavour. Bruising, breaking, processing, and damage while handling or harvesting are all examples of mechanical losses. Climate conditions like low or high temperatures, unsuitable storage atmospheres, and high humidity are all related to physical losses. Chemical and metabolic losses can also be mediated by physical factors (Mohammed, 2014) [19]. Weight loss as a result of respiratory heat loss is considered a physiological loss. Infection and pathogen damage are more likely to occur during wilting, senescence, ripening, and wilting. In contrast to perishable crops, where losses are caused by mechanical, physiological, and microbial factors, biological and microbiological variables are significant in seed. Secondary crop losses caused by improper equipment, technology, and control handling are the variables that promote initial crop losses. Lack of harvesting tools, expertise, packaging, handling, adequate containers, suitable transport, drying and storage conditions, correct processing technology, and competent management are the contributing factors (Kiaya, 2014) [6].

3. Weight loss

Slimming down loss of weight is not always an indication of crop loss. Weight loss may be caused by a decrease in moisture content. Recognizing shrinkage factor is a useful technique in business transactions. If moisture loss is not taken into consideration when grading for price control, it might result in financial loss. Feeding birds, insects, rodents, and microbes can cause weight loss. By comparing the weight before and after being stored in the bag, weight loss can be calculated. Additionally, an increase in weight may result from an increase in moisture content brought on by water production in the seed brought on by insect infestation. Weight loss may be difficult to notice if insect infestation increases the moisture content of the seed or if insects devour the seed and leave behind dust (Boxall, 2001) [22]. A useful mass of infested and non-infested seeds is crushed into flour and their weights are compared in order to identify these losses. Infested mass will produce less flour than sound mass, as will be seen. Be on the lookout for unethical techniques that adulterate rocks, soil, sand, or water to compensate for weight loss. Therefore, it is necessary to evaluate both the amount of foreign matter present in the yield as well as variations in moisture (Grolleaud, 1997) [23].

4. Quality decline or loss

Consumers place a high value on quality, and local merchants have various standards for judging it depending on the situation. Size, shape, and appearance are affected by biochemical elements such acidity, sugars, flavour, and fragrance. Contamination and the presence of foreign debris, such as bug pieces, rat hair, excrement, weed seeds, dirt, glass, and plant parts, can also cause quality degradation. Pesticides, oils, poisons created by fungi, soluble insect excrement, and dangerous organisms transferred by rodents are among the contaminants that are challenging to remove. Consumers boosting the standard norms will result in an increase in loss potential (Lipinski *et al*., 2013) [24].

5. Nutrient loss

The loss is based on the qualitative and quantitative nutritional value lost to the human population, which has an impact on that people's nutritional state. This is primarily brought on by pests feeding on particular seed parts. Plodia and Ephestia consume the seed embryo selectively while removing the vitamin and protein content. Because so many pests consume cereal seed bran, the vitamin content is decreased. Selective feeding of Liposcelis spp. on rice bran and embryo. Weevil consumes endosperm and rejects the presence of carbohydrates (Grolleaud, 2002) [23].

6. Reduction of seed viability

It is related to the decline in seed viability. Temperature, excessive respiration, moisture content, infestation, light, and infestation-control techniques could all be contributing factors to the losses. When compared to other insects, those that attack the embryo only suffer significant germination losses. Standard germination tests can be used to identify seed loss (ISTA, 1966) [26].

7. Financial loss

Direct effects (the aforementioned causes) or indirect effects are both responsible for commercial losses (cost of preventive action or equipment). There could be a loss of reputation, financial loss, and loss brought on by legal action.

Commercial loss might have an impact on international trade. With expertise and understanding, losses can be quickly minimised. Inappropriate storage is not always the cause of postharvest losses. The degradation of wheat seeds may be caused by biological, physical, or mechanical reasons. To get high-quality products from the farm to the market, it is necessary to expand the intervention approaches. For instance, Somalia and Malawi declined to accept the corn because of insect spread after the Tanzanian outbreak of pest in the maize crop (Tyler *et al*., 1990) [27].

8. Damage based on temperature
Fresh goods rapidly decay when exposed to high-temperature sun radiation. The problem should be avoided by providing adequate ventilation and cooling for the crops. As temperature rises, respiration likewise rises. Similar to this, crops may suffer damage from low temperatures between 0 and 2°C. However, several plants from tropical and subtropical regions shown resistance to chilling injuries at 12–14°C. When a product is separated from its environment, chilling damage (skin pitting, discolouration, uneven or irregular ripening, and sensitivity to quick deterioration) become evident (Lipinski *et al*., 2013) [24].

Estimation of losses
1. Estimation of seed losses in storage
Insects, rodents, and moulds are the main causes of seed loss during storage. Although many scientists have previously been interested in this topic, more effective methods must yet be developed in order to prevent insect-related seed loss. By boring or eating seeds, insects can cause both qualitative and quantitative loss; weight loss has received more attention (Boxall, 2002) [28].

2. Insect related weight reduction
The evaluation is done by collecting samples of the seed at different points after storage and comparing the samples to see how they have changed. To estimate storage losses at various times, measuring amount loss with successive samples taken at various intervals will be employed. Each seed batch's sample collection and quantity loss are evaluated in accordance with this. Samples must be taken in bulk stores without disrupting the pattern of infestation. When further regular sampling is not practicable, three samples must be taken: the first at the beginning of storage, the second at the halfway point of the storage period, and the third at the end of the seed's storage duration. It is observed that utilised seed and quantity loss follow a pattern (Boxall, 2001) [22].

3. Techniques for calculating weight loss
When additional sampling is possible, two techniques are employed to estimate the weight loss of the insects: the volumetric approach and the thousand grain mass (TGM) method. When further sampling is not practicable, count and weight procedures as well as converted percentage methods are employed (Boxall, 2002) [5].

4. Volumetric approach
Bulk density method and standard volume weight (SVW) are two names for the volumetric approach. By using equipment, this is utilised to determine the bulk density of a clean sample. From the sample of seeds taken at the start of the storage period, SVW is calculated, and losses are calculated. Using a standard volume container, this method precisely measures the weight loss caused by grain boring insects and moisture variation over time. Moisture can be treated as a constant term and the crop as dry matter in the stand volumetric method to establish an appropriate ratio for moisture content and dry weight of seed. Changes in moisture content, however, can also have an impact on volume and frictional characteristics. Because there is a direct correlation between sample volume and moisture content, the seed should be packed loosely. Calculating the standard volume of dry matter at various moisture contents is important to keep the moisture constant. The procedure takes time, care, and a well-equipped laboratory (Adams, 1978) [28]. Weight of insecticidal dust, which sticks to the seed surface and increases the volume of seed and frictional character, is another factor that influences sample volume. The process of sieving can be helpful in removing dust. Volumetric phenomena, however, are less useful since losses are overestimated (FAO, 2013) [29].

5. Using the mass in thousand grains
With a fixed number of seeds instead of a constant volume, this method varies from the volumetric method. This indicates that the weight of the seeds is multiplied by 1,000 and adjusted for dry matter. It is determined by weighing and tallying the seeds in a particular sample. Measurements are taken at the start of seed storage to establish a baseline reading, which is then used to compare future measurements (Reed, 1987) [30].

6. The count and weight approach
When the baseline readings of seed storage are not collected at the beginning of the season, the method sometimes called "Gravimetric method" is used. This estimation makes use of a sample of 1000 seeds and a basic medium. After separating the damaged seeds, the weight and quantity of seeds in each sample fraction are calculated. The values are then entered into the ensuing equation to determine the outcomes:

$$\text{Wt. loss } (\%) = \frac{(UxNd)-(DxNa)}{U(Na+Na)} x100 \quad (1)$$

Where,
U = weight of the undamaged seeds (g),
D = weight of the damaged seeds (g),
Na = the number of the undamaged seeds, and
Nd = the number of the damaged seeds

For a single sample, this approach does not require the moisture content of the distinct fraction, and the changes in assumptions are most likely negligible. The method does take into account concealed infestation in the damaged category, as well as insect-random seed infestation, which is not always accurate (Adams and Harman, 1977) [31]. For low levels of infection and many infestations in large seeds, the approach can produce false findings. The technique is helpful for rapid estimating at extremes at the field level. Many improvements have been developed in order to overcome the biased estimation. For instance, different-sized seeds can have hidden infestations due to their varying moisture levels. Before counting and weighing, these seeds are categorised and graded according to size (Boxall, 1986) [32]; seriously harmed grains are segregated, and readings of hidden grains are collected after infestation appears (Ratnadass *et al*., 1994) [33]. The hidden infection can also be determined by dissecting seeds, however this procedure is time-consuming and runs the risk of changing the moisture content of the seeds due to calculations that must be conducted on dry matter.

7. Vertebral pest losses

It is impossible to measure the damage caused by vertebral pests because they remove the entire seed from the sample, like rats and birds do. By comparing the reference % of seed loss and average seed weight, the loss can be calculated (Boxall and Gillett, 1982) [34]. Than estimate the losses caused by pests and rodents, population studies and feeding experiments are used, although their accuracy is frequently inferior to that of increased efforts (Hernandez and Drummond, 1984) [35]. Pests only consumed stored grains as part of their diet; feeding experiments may overstate the loss of seeds that were kept in storage. It's debatable how much seed rodents actually destroy. When compared to losses to buildings, structures, personal property, and potential health issues, crop loss from rodents comes in last.

8. Weight loss by molds

Mold-infected seeds will lose weight, and the weight loss can be measured using the same technique as weight loss caused by insects. The weight loss from the mouldy seed increased as a result of moisture absorption, allowing for compensation of the mould loss. Due to the lack of obvious signs of infection on the surface, the procedure is not very effective in determining the actual loss of seeds, and the seeds may be mistaken for undamaged ones. Damaged seeds are distinguished from undamaged seeds in order to calculate the weight loss caused by mould. Moldy seeds are then distinguished from damaged seeds. Mold will cause a loss of weight that is equal to its own weight (Boxall, 2001) [22].

9. Total seasonal loss

The losses listed above represent the starting losses for a particular period of time. The image might not be accurate; there must be a connection between the patterns of seeds used during a season. In an undisturbed stored crop, insects will be responsible for the majority of the loss if sample loss is 10% throughout the course of storage seasons. Due to insect exposure throughout various time periods during the season, the seeds will lose variable amounts at different intervals of time (Boxall, 2001) [22]. With time, as pest infestation grows, the percentage of seeds lost increases gradually. When the moisture content of the seeds has been taken into account, the loss in seeds can be estimated by weighing the seeds both when they are still in the store and when they are taken out. By deducting the loss brought on by other insects, the loss not caused by insect damage can be found. The actual seed losses after storage are far lower than the estimated amount. Numerous loss assessment procedures for businesses and farms have been reported (Boxall, 1986) [18]. To acquire the greatest assessment results, it's important to develop a process that works for each commodity. Small numbers of losses were reported for commercial operations, but none were reported for cooperative level storage. The situation is a reflection of the quick purchasing and selling of seeds in developing nations. This paints an image of private sector involvement (market emancipation and parastatal marketing), but there is little data on storage loss. Entrepreneurs might keep a lot of seed in storage for a while. However, this level of farm storage has been raised by the private sector. To measure the storage losses in agricultural storage, a lot of time, energy, and money were expended, but the endeavour was not as successful as the prior initiatives. Additionally, the study ought to be conducted with the post-harvest industry as a whole, and exact measurements ought to be avoided. A social survey might be useful in identifying the farmers' issues so that loss estimation and the proper measuring methods can be used (Goletti and Wolff, 1999) [36].

Harvest and maturity indices

Commodities that have been harvested or handled carelessly may have bruises and other injuries, which have a negative impact on their market value and render them unsightly. Injuries create a place for microbial attack that leads to rotting, increased respiration, and a reduction in storage life. Crop loss and serious seed damage might result from improper harvesting (FAO, 2011) [37].

1. Harvesting and handling

The initial stage of postharvest and the final stage of crop production is harvest. The manner and state of the harvest have an impact on how the crops are handled, processed, and stored moving forward. Because of their high water content and premature harvest, seeds lose quality and degrade in storage. Crops that are harvested too early suffer biological and physical losses as a result of repeated watering and drying (Kiaya, 2014) [6]. After harvest, wet seeds must be promptly threshed and dried.

Different plant parts are harvested using different techniques: forage is harvested by trimming the entire plant; cereal seeds are harvested by threshing and cleaning a portion of the plant; and straw or chaff is harvested for further processing. Small-scale producers use threshing combines and harvesters (equipped by community organisations) to perform threshing and harvesting, but in developing nations, threshing and harvesting by hand is unlikely to cause harm to or degradation of stored crops. Mechanical harvester equipment is used by large-scale commercial growers, although its application is constrained by the growth of cash crops. Harvesting by hand lowers the danger of crop damage in storage after harvest. Threshing combines were used for small-scale production to perform the harvesting process (Kiaya, 2014) [6]. For the purpose of threshing, traditionally, seeds are thrashed with a stick or against a hard surface (wooden bar, log of wood, stone, and wooden metal or tub). The approaches may result in cracks or damage to the seeds, however walking on the seeds will be a less harmful method. Sorghum, millet, or wheat grain heads or ears are frequently bashed with sticks. However, hand harvesting is physically taxing and is not always the most cost-effective option. High-level damage is caused when maize cobs are pounded with sticks or shelled by hand. To lessen seed damage, mechanised threshers are designed; the models are quite complex. Threshing, cleaning, or combine harvesters are used to harvest seeds in tandem with other processes. Mechanical machinery created specifically to collect grain seeds are used for large-scale harvesting (Boxall, 2002) [5].

Seed Storage Principles

When stored at ambient or natural temperatures, seeds react quickly to changes in temperature, the presence of oxygen, and relative humidity. By adjusting the humidity, temperature, and oxygen levels, one can influence the metabolic activity, age, and longevity of seeds (Mohammed, 2014) [19]. Prior to storage, the seed's moisture content must be reduced up to an acceptable level because desiccation could cause damage to the seed. Due to the lower humidity, seeds can be kept for a longer amount of time. As a general rule, if the seed moisture level is between 5 and 14 percent, reducing the moisture content to 1 percent doubles the life of the seed. Seeds need to be stored in a cool environment since higher temperatures have a greater impact on higher moisture content. When the temperature is lowered by 5 °C, the life of the seed doubles and is applicable between 0 and 50 °C. Hermetic storage in a sealed container allows for the regulation of oxygen levels, reducing both the physiological ageing of the grains and the physical harm caused by insects and microbial development (Harrington, 1972) [38].

Seed storage facilities

Grains and seeds are hardy plants that typically only need straightforward storage arrangements.

1. On farm storage

The seeds must be protected against biological elements including microbes, birds, rodents, mites, and insects as well as physical harm from high temperatures, inclement weather, snow, and rain in order to store them safely outside or indoors. Many nations store the majority of their seeds using the agricultural storage method (Semple, 1992) [39]. The storage structure has a range of 100 kg to a few metric tonnes in terms of capacity. According to the weather, modifications to locally made storage structures could be made. There are a few conventional storage facilities. High-density and high-molecular-weight polyethylene, plywood, aluminium, ferro-cement, and other materials are frequently used to make the bins. Plywood is the most ideal material for storage structures, and hermetic storage underneath structures come in a variety of sizes and configurations. This increases the amount of carbon dioxide and decreases the amount of oxygen, which makes seed storage dangerous for insect and microbial attack (Shejbal and de Bioslambert, 1988) [40]. Although traditional approaches are less expensive, they are ineffective against microbial and pest attack. At the agricultural level, seeds are also kept in silos or metal bins.

2. Storage in bags

While silos for bulk storage, seeds elevators, and flat storage structures are utilised in rich countries, seeds are often stored in traditional warehouses in underdeveloped countries in gunny or woven polypropylene bags (Kennedy and Devereau, 1994) [41]. The procedure of bag storage is time-consuming and expensive, and there is a higher risk of biological losses and seed spilling. Due to warehouse flooring that isn't acceptable, there can be an issue with humidity and water seepage. Bags don't require any aeration equipment or fumigation facilities. The concept will not be viable in underdeveloped nations because of the tiny farm size and less expensive manual labour.

3. Bulk storage

There are two ways to store seeds in bulk: vertically (in silos or bins) or horizontally (on floor stores). Horizontal stores are made up of specifically built floors of warehouses with adequate ventilation on the floor and walls that are reinforced to support the weight of the seeds. Bins and silos are specially made storage units that can be circular or square, clustered or standalone, and include unloading and loading processes that typically include aeration systems. Belowground or partially belowground storage or enamelled, sealed silos for the storage of seeds with a high moisture content are further options for bulk storage. The procedure is suitable for handling or storing seeds in bulk (Bailey, 1992) [43].

4. Hermetic storage

The seeds are protected from biological harm by the conventional techniques of storage in the natural oxygen build-up and lower oxygen levels. For seeds with lower moisture content and reduced infestation of insects per kilogramme of seeds, the conventional storage approach is ineffective. In hermetic storage, the controlled environment treatment and fumigation must be augmented (Alvindia, 1994) [43].

5. Outside storage

In the absence of permanent storage, this is the interim measure of storage. The stacks of seeds are covered with polyethylene covers, and the godowns and silos are constructed on plinths. In a week, the cover must be raised to the seventh or eighth layer in order to effectively aerate the stacks. For wheat and paddy, the cover and plinth (CAP) technique is frequently utilised. However, there is a danger that the cover will be damaged by wind or rain, making effective fumigation impossible (Semple, 1992) [39].

6. Guidelines for quality seed storage

By specifically building the tiny stores to silos or warehouses that play a protective function against unfavourable temperature conditions, ground water, rain water, pests, and thefts, the quality of seeds may be maintained. The store's layout and contents need to be managed (Kiaya, 2014) [6].

Moisture management

It is necessary to have a water disposal system and a well-designed roof (overhung or gutter) to stop water from flowing into the store. Water is moved away from the stores through drains. To stop water from dripping into the store, side-by-side connecting of shelves should be avoided in large warehouses. Water-resistant floors and walls protect against ground water, while a raised floor and efficient drainage systems reduce the risk of flooding. To regulate the humidity inside the storage structure, a suitable ventilation system is required (Boxall, 2001) [22].

It is challenging to regulate temperature in storage structures; particular design components are required. The use of controlled ventilation can be used to measure temperature. Insulated shops can control temperature throughout the chilly night. Building stores in an east-west direction with reflective materials outside can be an efficient way to manage heat. The heat of the storage structure can be further reduced by thick walls and large roofs (for shade). To change the temperature in a store, heaters and refrigerators can be placed; the machinery works best in insulated stores. The degree of insulation in these storage structures, however, is dependent on the environment (Longstaff, 1988) [44].

Controlled Atmosphere Storage (CAS) and Modified Atmosphere Storage (MAS)

To create a controlled atmospheric composition around seeds that differs from air (78.08 percent nitrogen, 20.95 percent oxygen, and 0.03 percent carbon dioxide), changed atmospheric conditions add or remove gases from the environment. This also entails a decrease in oxygen and an increase in carbon dioxide content. The degree of control between CAS and MAS varies, while CAS is more precise.

The method is applied to make whole-store fumigation easier (Paster *et al*., 1991) [45].

Transportation

Commodities being moved from fields to storage facilities may sustain some damage, which could subsequently result in produce degrading. The goal here is to keep the produce dry and free of moisture. Seeds from the polluted container carry a residual risk of insect infestation. Vibration during transport, bad vehicle and road conditions, poor driving, unsafe container stacking, the use of inappropriate containers, and irresponsible handling can all result in mechanical injuries. Produce loses moisture due to overheating caused by the sun or a car's engine, which promotes natural decay and decomposition(Boxall, 2002) [5].

Quality and safety

The class, degree, excellence, or superiority of a crop is determined by the quality of the product. The set of traits, qualities, and attributes that provide a commodity value as food or a source of the following crop's production collectively make up its quality. The marketing quality of the crop might be impacted by foreign material or high moisture content. In seeds, high moisture levels may promote shrinkage or biological and biochemical harm. Low moisture can break or harm the seeds in paddy rice and lentils. Broken and discoloured seeds have a lower marketable quality and are more susceptible to insect and microbial attack (Boxall, 2001) [22]. The fundamental goal of a farmer is to produce products that appear to be good and have few visible flaws. These products must also perform well in terms of yield, disease resistance, ease of harvest, shipping quality, and meeting national and international quality standards. The buyer or consumer places more value on looks; they are anxiously interested in good seed and long-term storage. For distribution to suppliers and the market, the product's safety must be guaranteed (Mohammed, 2001) [46].

Postharvest quality evaluation methods

After harvest, there are two ways to evaluate the crop's quality: analytically or objectively, and subjectively or sensually (Ranganna, 2000) [47]. The subjective method has difficulties when assessing the quality of hazardous materials (Jha SN, Garg, 2010) [48]. The nature of an objective technique can be destructive or non-destructive. Commodity sorting by hand is inefficient, expensive, unreliable, subjective, tiresome, and slow. Regarding varietal and temporal dependence, food exhibits complicated and dynamic activity.

Visual inspection, x-ray imaging, computed tomography, near-infrared spectroscopy, thermography, electromagnetic testing, liquid penetrant testing, magnetic particle testing, acoustic emission testing, infrared and thermal testing, magnetic resonance imaging, electronic nose, and other non-destructive methods are among the physical principles-based non-destructive methods (Siddiqui, 2015) [49].

The advantages of quality evaluation or grading are as follows:

1. It makes it easier to buy a product you haven't seen.
2. Incentives for quality and safety improvement.
3. Grading gives the market data context.
4. It makes it easier to compare prices and quality.
5. It lessens the likelihood of deception and dishonest marketing.
6. The procedure can enable various marketing strategies, including commodity exchanges, futures trading, inventory credits, credit letters, and expediting the resolution of disagreements over composition or quality (Smith, 1995) [50].

Machineries and requirement for a good seed processing plant

- Seed cleaner and grader (Preferably 4 screen) with a pre cleaner.
- Moisture meter
- Seed Treater
- Gravity Separator
- Indented cylinder
- Weighing machines
- Balance to weigh from 1 kg to 25 kg.
- Platform balance to weigh up to 300 kg.
- Bag closer
- Seed sampling triers
- Wooden pallets, fumigation covers, tarpaulins
- Stock and name boards
- Vacuum cleaner
- Chemical sprayer
- Exhaust Fans
- Ceiling fans in processing shed
- Proper and sufficient light arrangements
- Fire extinguishers
- First Aid Box
- Separate room or facility for Agency Staff
- Toilets for gents & ladies workers.
- Pucca floors, plastered walls.

All of the equipment, including seed separators, elevators, conveyors, and storage bins, should be set up so that seeds flow continuously from start to finish while still being adaptable enough to avoid a machine when returning to a part for re-cleaning.

Conclusion

Demand for food has multiplied due to the growing population and changing lifestyle. A unit called a seed is utilised to produce the following generation in addition to being eaten as food. Post-harvest management and seed quality preservation are the two viewpoints in seed industry that require the most focus. Though, significant progress has been made in recent years in the development of novel packaging, storage, and transport systems, pest control, and seed-borne disease management for market access. However, more study and technological advancement should be devoted to investigating genetic components of desirable qualities such stress resistance, resistance to postharvest illnesses, and pest management. Researchers have to make an effort to develop integrated strategies for seed postharvest management. To preserve seeds for extended periods of time without affecting their genetic makeup, seed biologists should attempt to further their research. For higher-quality harvests, seed quality needs to be preserved. These days, the main issue in developing nations is seed maintenance. Better postharvest handling and seed storage techniques must be developed in order to be more cost-effective, practical, and effective. Translation of information into agricultural outcomes should be the main goal for researchers.

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