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6. Seed Storage: General Principles and Factors Affecting Seed Longevity During Storage

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Abstract:

An effective seed program always focuses on conserving the seed purity (both physical and genetic), seed quality like germination, vigour, and seed health during storage etc. This includes appropriate seed handling, maintaining proper temperature and humidity, and sanitation practices during storage. Alternative choices for storing seeds, such as on-farm seed storage, may be considered where conditioned storage facilities are not found. Seed storage is important for preserving high-quality seed from harvest to successive growing seasons. Seeds are stored for multiple purposes, which includes market demand, catastrophic events, hybrid seed production, genetic stock conservation, and long-term use. According to their behavior in storage seeds are mainly divided into orthodox seeds or recalcitrant seeds. Their longevity increases with decrease in storage temperature and the relative humidity of the storage environment. Seed degradation occurs during storage even under dry conditions due to physiological oxidation and presence of pests and pathogens.

Keywords:

vigour, orthodox, longevity, deteriorate seeds, storability.

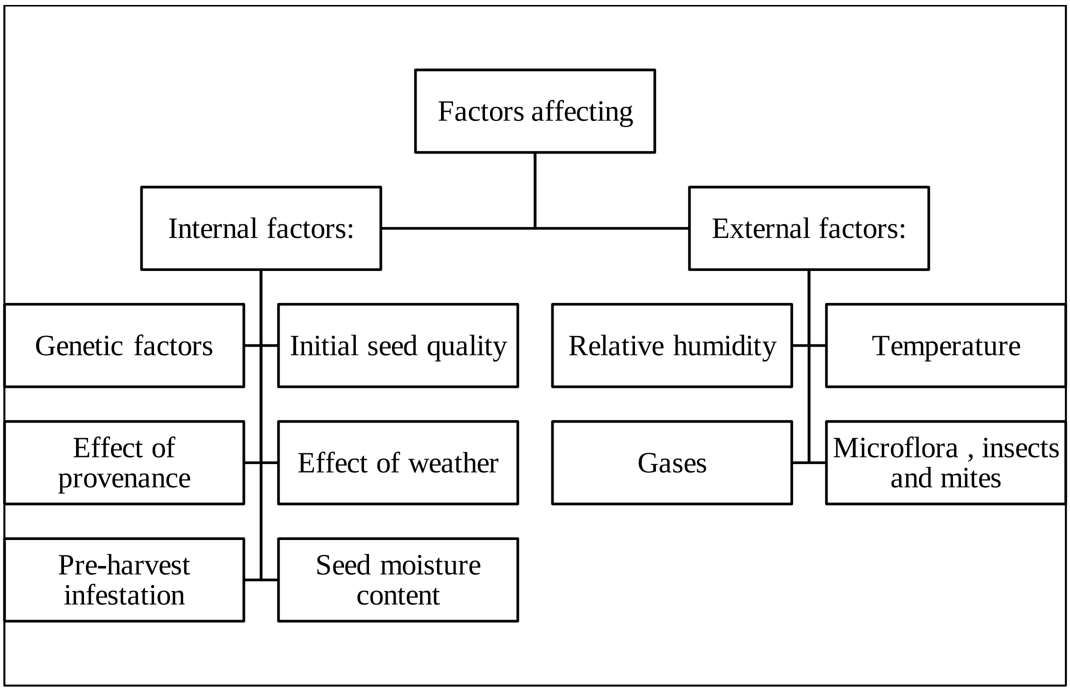
6.1 Seed Storage:

Seed storage is an important aspect in seed programs that aims to maintain the seed quality from harvest to sowing and for the market demand, genetic conservation, breeding purpose etc. (Dadlani et al., 2023). Seeds age during storage resulting in a sink in quality of stored seed ultimately leads to loss of viability if not stored properly (Harrington, 1972). Seed storage is defined as storing the seeds in their original state till they are needed for sowing or any market demand, breeding purpose etc. Proper care should be taken to maintain the viability and vigour at every stage of processing and distribution. Storage is a fundamental technique to regulate the physiological quality of seeds. Several factors, including temperature, moisture content, insect pests, and diseases, can alter storage conditions. Improper maintenance of these conditions might result in an overall reduction in germination and vigor (Dadlani et al., 2023). High-quality seeds with good genetic purity, physical purity, germination potential, and vigor are essential for successful storage (Dadlani et al., 2023).

6.2 Principles:

- Well cleaed as well as high germinable and vigour seeds should be stored.
- Dried the seeds to safe moisture limits.
- In Seed stores proper sanitation should be maintained.
- Seed storage conditions should be dry and cool.
- Effective storage-pest control.

6.3 Factors affecting seed storage:



6.3.1 Internal Factors:

A. Genetic Factors:

The genetic makeup of the seed controls how it can be handled. Numerous varieties have a short life span e.g.- onion, soybeans, ground nut etc., Based on the biological make up seeds are classified into Micro biotic – short lived, Meso biotic- medium lived and Macro biotic – long lived. The stress during storage in seeds is mainly due to accumulation of free radicles i.e. reactive oxygen species (ROS).

Increase in this type of free radicles leads to ageing and complete loss of their viability. (Shvachko and Khlestkina, 2020) Seed aging rates are influenced by genetic factors that determine seed color and weight as well as the activity of protein non-enzymatic glycosylation processes, lipid peroxidation, cell membrane structure, generation and neutralization of ROS and free radicals, among other processes (Frolov et al., 2018).

B. Initial Seed Quality:

Seed lots with plump, healthy, undamaged seeds can be stored longer than deteriorated seeds. In comparison to low viability seed, Barton (1941) discovered that high viability seed exhibits a significantly greater resistance to unfavorable storage environmental conditions. The deterioration of seeds proceeds quickly once they begin. Various factors like initial moisture content, packaging, temperature and humidity affects the storage of seed (Aqil, 2020). High quality seeds with low moisture content are stored low temperature and humidity to maintain viability (Ellis et al., 1988).

Deterioration in seed quality is associated with decreased peroxidation and decreased antioxidant enzyme activity (Sheidaei et al., 2020). Small seeds escape damage while large seeds, such as soybean, lima bean, and bean are more likely to sustain extensive damage. Spherical seeds typically offer more protection than flat or irregularly shaped seeds. The mechanically injured seed suffered greatly and lost its viability and vigor very quickly.

C. Effect of Provenance:

The seed provenance or the place where the seed is grown can significantly affect the seed quality in storage in various plant species. The place where the seed crop was produced greatly influences the storability. (e.g.) Red clover seeds grown in Canada stored for 4 years with 80% germination whereas seeds grown in England and New Zealand stored only for 3 years with 80% germination.

This is due to different climatic conditions and soil types prevailing in different places. Seed provenance affects the germination capacity and cause changes in germination over time during storage for some tropical dry forest tree species (Cervantes et al., 2014). Also, the seed provenance affects the seed weight, germination and moisture content in coastal dune species *Cakile edentula* (Álvarez-Espino et al., 2019).

D. Effect of Weather:

The most obvious pre harvest factor affecting seed viability and storability is weather, especially seasonal changes. Farmers and seeds men alike know the perils and risks of excessive moisture and freezing temperatures during the later stages of seed maturation and post maturation stand in the field. Fluctuating temperature during seed formation and maturity will affect seed storage.

Pre-harvest rain also affects the quality parameters like germination, viability etc. Seed storage conditions, particularly temperature and humidity, significantly impact seed quality over time (Aqil, 2020). Low temperature and humidity can help maintain seed viability and vigor, even for deteriorated seeds. Field weathering and mechanical damage during harvest can negatively affect seed quality, with these effects increasing linearly during storage (Tana Balesdent Moreano et al., 2011)

E. Pre-Harvest Infestation:

Pre-harvest infestation significantly impacts seed storage quality and longevity. Studies show that pre-harvest sprays of insecticides and botanicals can effectively control pulse beetle infestation in mung bean during storage (Bhalekar et al., 2023). Similarly, pre-harvest sprays of Spinosad and Malathion reduced the incidence of Angoumois grain moth in paddy during long-term storage (Rao, 2020). Pre-harvest fungal contamination, particularly by Aspergillus flavus, accelerates maize deterioration during storage (Chatterjee et al., 1990). Seed-borne fungi can significantly reduce seed quality and longevity, and may produce harmful mycotoxins (Martín et al., 2022).

As seed-borne fungi affect seeds hence the need to ensure that there is early identification and diagnosis is important in seeds. For growers it is quite vital to adhere to measures that will enhance seed quality in terms of control measures taken during the pre-harvesting stage. And also, methods of storage that will minimize losses due to storage.

F. Seed Moisture Content:

Seed moisture content is the primary determinant of storability. The most significant element affecting a seed's viability during storage is its level of moisture. Generally speaking, storage life drops as seed moisture content rises. Mold growth can cause seeds kept at high moisture content to lose moisture quickly. Extreme desiccation or hard seededness in certain crops can also result from extremely low moisture content, below 4%.

Drying seeds to safe moisture contents is essential because a seed's survival is primarily dependent on the moisture content present in a seed. However, factors such as the time of storage, the style of storage structure, and the kind or species of seeds used all affect the moisture content of the seed. Seed drying to a moisture content of 10% seems to be suitable for cereals stored under normal conditions for a period of 12 to 18 months. However, drying to a moisture level of 5–8%, depending on the type, may be required for storage in sealed containers.

The quantity of water in a seed is known as its seed moisture content, or SMC. In cells, water may be found both freely and attached to other chemicals like protein and carbs. The weight of water in a seed is stated as a percentage of the seed's overall weight prior to drying; this is referred to as the wet-weight (wb) or fresh-weight basis (International Seed-Testing Association [ISTA], 2005). Wet weight - dry weight over wet weight x 100 equals SMC (% wb). Another way to indicate moisture content is on a dry weight basis (db), which is the weight loss expressed as a percentage of the seeds' dry weight. Wet weight minus dry weight over dry weight x 100 is SMC (% db). (Rao et al., 2006)

Copeland (1976) conducted research on the link between moisture and seed and found that the seed's water content is understood to be: "- Tightly bound to ionic groups such as amino or carboxyl groups is bound water. It surrounds the big molecules in a monolayer. Sometimes referred to as bulk water, adsorbed water is retained loosely by forming bonds with amino and hydroxyl groups in a multilayer above the bound water's monolayer. Capillary or solution water that is only retained by capillary force is known as free water. Plant seeds are hygroscopic, meaning that the relative humidity of their surroundings and their moisture content balance each other out.

6.3.2 External Factors:

A. Relative Humidity:

When the amount of water vapor in the air is divided by its maximal capacity to hold water at a particular temperature, the result is the relative humidity. In order to determine how long seeds may be stored, two key criteria are temperature and relative humidity. When exposed to certain amounts of ambient humidity, seeds acquire a certain and distinct moisture content. We refer to this moisture content as equilibrium moisture content. A given type of seeds equilibrium moisture content at a as temperature drops, relative humidity tends to rise. As a result, relative humidity and, to a lesser extent, temperature determine how well seeds retain their moisture content during storage. There is no net change in the moisture content of seed at equilibrium.

B. Temperature

The life of a seed is also significantly influenced by temperature. With rising temperatures come an increase in mold and insects. The seeds are more negatively impacted by temperature the more moisture they contain. One good way to preserve seed quality in storage is to lower the temperature and seed moisture content.

The following thumb rules by Harrington are useful measures for assessing the effect of moisture and temperature on seed storage. These rules are as follows.

- For every decrease of 1% seed moisture content the life of the seed doubles. This rule is applicable between moisture content of 5-14%.
- For every decrease of 5^{o}C in storage temperature the life of the seed doubles. This rule applies between 0°C to 50°C.

- Good seed storage is achieved when the % of relative humidity in storage environment and the storage temperature in degrees Fahrenheit add upto one hundred but the contribution from temperature should not exceed 50°F.

C. Gases:

A rise in O_2 pressure shortens the shelf life of a seed. The atmosphere's N_2 and CO_2 content will lengthen seeds shelf life. Research on seed storage have also analyzed the signs of the gas mixtures on viability and seed health. Different research works have shown that storage in controlled atmosphere influences the quality of seeds. It is therefore clear that whereas high temperature and moisture content are detrimental to seeds, high concentration of carbon dioxide at fluence does not have a large undesirable impact on seeds (Rathi et al., 2000). A optimum atmosphere can help retain a better seed germination rate with less production of volatiles in some types, (Han et al., 2021). On the contrary, depending on the species, some studies indicate an increase in viability of the preserved seeds if they have been stored on an unsealed vial rather than vacuum or nitrogen (Bass et al., 1963).

D. Microflora, Insects and Mites:

Microflora, insects, and mites can significantly impact seed storage quality. Seed treatments with physical, chemical, and biological agents can help suppress pathogens and pests that reduce seed vigor and viability during storage (Chormule et al., 2018). Mite infestations can have varying effects on stored wheat, with some species like Lepidoglyphus destructor potentially slowing the loss of seed germination (White et al., 1979). Insect infestations, such as Tribolium castaneum, can increase fat acidity, decrease germination, and alter microfloral levels in stored wheat (Lustig et al., 1977). The presence of arthropods in stored products can lead to both direct and indirect health hazards, including food contamination with allergenic fragments and the creation of favorable conditions for fungal growth and toxin production. Insects may also contribute to the spread of microorganisms and antibiotic-resistant bacteria in food (Hubert et al., 2018). All these species have the potential to cause harm that ends in their loss of viability. Temperature, relative humidity, and seed moisture content all affect the activity of the microflora. Fungicide treated seeds have a longer shelf life. Longer periods of storage will also benefit from fumigation to reduce insects. Fumigants - (e.g.) methyl bromide, hydrogen cyanide, ethylene dichloride, carbon tetra chloride, carbon disulphide and naphthalene and aluminium phosphine.

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