Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 01 (JAN-FEB, 2026)
Available online at http://www.agriarticles.com


# Physical and Physiological Changes in Seeds during Storage

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Seeds are metabolically quiescent yet biologically active structures that undergo continuous physical and physiological alterations during storage, ultimately influencing their longevity and planting value. Seed longevity is defined by the duration for which seeds retain viability and vigour under specific storage conditions (Nadarajan *et al*.,2023). During storage, progressive seed ageing results in deterioration characterized by loss of membrane integrity, enhanced lipid peroxidation, accumulation of reactive oxygen species (ROS), decline in antioxidant enzyme activity, reduced metabolic efficiency, and impairment of cellular and genetic components (Malik *et al*., 2013). These changes are strongly regulated by intrinsic factors such as seed structure, chemical composition, hormonal balance, and genetic makeup, as well as extrinsic factors including temperature, relative humidity, and seed moisture content (Shelar *et al*., 2008). The seminar highlights the developmental acquisition of desiccation tolerance and protective mechanisms during seed maturation, followed by physiological decline during ageing. Strategies to enhance seed longevity, such as optimized harvest at physiological maturity, moisture regulation, low-temperature storage, improved packaging systems, and application of seed treatments, are discussed. A comprehensive understanding of the mechanisms underlying seed ageing is essential for improving seed storage practices, maintaining seed quality, and ensuring sustainable crop production.

**Keywords**: Seed Storage, Seed Deterioration, Physical Changes, Physiological Changes

## Introduction

Seeds are the fundamental biological units responsible for the perpetuation of plant species and form the foundation of global agricultural production systems. In agriculture, the use of high-quality seed is one of the most cost-effective inputs for achieving higher productivity, uniform crop establishment, and stable yields. A seed is a ripened ovule consisting of an embryo, reserve food material, and a protective seed coat, with the inherent capacity to develop into a normal plant under favourable environmental conditions. Seed quality is a dynamic characteristic that changes continuously from development on the mother plant until sowing. Although seeds attain maximum quality at physiological maturity, this quality cannot be preserved indefinitely, as seeds must undergo storage after harvest for varying periods depending on crop, season, and purpose. During storage, seeds remain alive but metabolically quiescent, yet slow and progressive changes occur that gradually impair their performance. Seed storage is therefore a critical link in the seed production and supply chain, as improper storage conditions accelerate deterioration, leading to reduced germination, poor seedling vigour, uneven field emergence, and significant economic losses, particularly in tropical and subtropical regions such as India where high temperature and relative humidity prevail. The changes during storage are broadly classified into physical, physiological, biochemical, and molecular changes, with oxidative stress, lipid peroxidation, protein degradation, and DNA damage playing key roles in seed ageing. Collectively, these processes constitute seed deterioration, an inevitable and irreversible phenomenon, and understanding these changes is essential for improving storage technologies, enhancing seed longevity, and ensuring sustainable agricultural production and conservation of plant genetic resources.

## Seed Storage

Seed storage is the systematic preservation of seeds under suitable environmental conditions from physiological maturity until sowing or loss of viability. During storage, seeds remain alive but metabolically quiescent, and the main objective is to maintain their viability and vigour for the longest possible period while minimizing deterioration. Since seed production and use are separated by time and place, effective storage is essential for seasonal planting and long-term conservation of breeder, foundation, and germplasm seeds. Although seeds respire slowly, continuous respiration depletes food reserves and accelerates ageing, with deterioration strongly influenced by temperature, relative humidity, and seed moisture content. Seeds are classified as orthodox, recalcitrant, or intermediate based on their tolerance to drying and low temperatures. Seed longevity varies with genetic makeup, initial quality, and post-harvest handling. As seeds are hygroscopic, high humidity promotes fungal and insect damage, whereas low moisture and cool conditions extend storage life. Therefore, proper seed storage integrates biological knowledge and environmental control to preserve seed quality and ensure sustainable agricultural production and food security.

## Seed Deterioration: Definition and Nature

Seed deterioration is the progressive and irreversible decline in seed quality during storage, resulting in reduced germination, vigour, and viability. It is a natural ageing process that begins after physiological maturity and is accelerated by delayed harvesting, improper handling, and unfavourable storage conditions. The extent of deterioration varies with genetic makeup, seed structure, reserve composition, and physiological condition at harvest. At the cellular level, it involves membrane damage, increased permeability, solute leakage, and mitochondrial dysfunction, leading to reduced metabolic efficiency. Biochemically, deterioration is associated with oxidative stress, lipid peroxidation, protein and DNA damage, and decreased antioxidant activity, ultimately impairing seed performance and longevity.

## Classification of Changes During Seed Storage

**(1) Physical Changes:** Physical changes are the most visible alterations occurring in seeds during storage and mainly affect their external structure and physical properties. These changes often act as early indicators of seed deterioration by increasing seed coat permeability and susceptibility to mechanical damage.

a. Loss of seed weight: May be due to the respiration or moisture loss during seed storage. During respiration stored food materials broken down thus causing weight losses. Loss of moisture may cause due to evaporation. Again, fungal attacks by *Aspergillus* and *Penicilllium* species consumes seed reserves like carbohydrates, proteins, lipids and stored grain insects such as *Sitophilus*, *Tribolium*, and *Callosobruchus* species are major causes of seed weight loss during storage.
b. Change in seed size and shape: Shrinkage or deformation caused by fluctuation in moisture content. Seeds shrink and wrinkled due to uneven drying. Distortion or deformation caused by insect feeding also reduces seed size.
c. Change in seed colour: Darkening, fading or discolouration due to oxidation of seed pigments, enzymatic browning reactions. Fungal growth and mould development also make the seed to appear whitish in colour
d. Seed coat cracking and splitting: Loss of elasticity of seed coat during prolonged storage and due to alternate wetting and drying. Rapid moisture loss or gain causing uneven shrinkage and expansion.
e. Increased brittleness: Seeds become hard and fragile, leading to breakage during handling. This leads to breakage during handling.

f. Insect and pest damage: Holes, powdering, and physical injury caused by stored insects. Feeding by storage insects on endosperm and embryo causes viability losses. Egg laying and larval development also occurs inside the seeds.
g. Mechanical damage: Damage during handling, processing, and storage operation. It is due to rough handling during storage and transportation and improper stacking and pressure in bags.
h. Reduced in bulk density and test weight: Caused by internal tissue breakdown and insect damage due to loss of seed moisture and reserve food materials. Insect feeding and hollowing of seeds leads to reduced BD and Test weight.

**(2) Physiological Changes:** Physiological changes involve alterations in metabolic and functional processes of seeds during storage and directly influence seed viability and vigour. Ageing seeds show reduced and delayed germination, poor seedling growth, and non-uniform field emergence due to impaired respiration, mitochondrial dysfunction, and reduced energy availability. Major physiological changes include:

a. Reduction in seed viability: Due to membrane deterioration and loss of cellular integrity and accumulation of toxic metabolites.
b. Loss of Seed Vigour: Decline in enzymatic activity and impaired respiration and metabolism leads to loss in seed vigour.
c. Increased respiration rate: Due to elevated storage temperature and activation of metabolic processes during ageing
d. Membrane Damage and Leakage: Lipid peroxidation of cell membranesand oxidative stress due to free radical formation
e. Enzyme Inactivation: Denaturation or degradation of enzymes and oxidative damage during prolonged storage
f. Depletion of Food Reserves: Continuous respiration. Utilization of carbohydrates, proteins, and lipids during ageing
g. Delayed germination: Degradation of mitochondrial membrane, leading to reduction in energy supply. Thus resulting in depletion of food reserves during respiration
h. Increased Membrane permeability: Ageing-induced membrane deterioration and lipid peroxidation caused by free radicals
i. Reduced Longevity of seeds: Continuous respiration and metabolic activity and depletion of protective compounds and food reserves
j. Decreased tolerance to optimal environmental conditions for germination: Reduced physiological flexibility due to ageing and impaired enzyme systems and metabolic pathways
k. Reduced seedling growth: Poor mobilization of stored food reserves and weak metabolic activity in aged seeds
l. Increase abnormal seedlings: Damage to embryo tissues and uneven or incomplete utilization of seed reserves

## Future Perspective

Future aspects of halogenation treatment in seed storability include the development of safer and eco-friendly halogen formulations, integration with polymer and nano-coatings for controlled release, and combination with biological and physical seed treatments for better protection. Crop-specific protocols and dose optimization will help avoid phytotoxicity. Halogenation has potential applications in gene banks for long-term seed conservation. Advanced research on physiological and molecular mechanisms will improve its efficiency. Commercial adoption, digital monitoring, and climate-resilient storage systems will further enhance its role in maintaining seed quality and food security.

## Conclusion

Seed storage plays a vital role in maintaining seed quality for successful crop production, but during storage seeds undergo unavoidable physical and physiological changes that lead to deterioration. Physical changes such as loss of weight, colour variation, seed coat damage, and insect infestation affect seed structure, while physiological changes including membrane damage, oxidative stress, enzyme inactivation, depletion of food reserves, and reduced metabolic activity impair germination and seedling vigour. These changes are influenced by factors like seed moisture content, temperature, relative humidity, genetic makeup, and maturity at harvest. Proper storage practices such as drying seeds to safe moisture levels, maintaining low temperature and humidity, using suitable packaging, and applying seed treatments can significantly slow deterioration and extend seed longevity. Therefore, understanding and managing the physical and physiological changes in seeds during storage is essential for preserving seed quality and ensuring sustainable agricultural production.

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