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OPTIMIZING SEED LONGEVITY: THE CRITICAL ROLE OF TEMPERATURE AND RELATIVE HUMIDITY

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ABSTRACT

Seed longevity is essential for agricultural productivity and the conservation of genetic resources. Temperature and relative humidity are the primary factors influencing seed viability during storage. Proper management of these conditions reduces post-harvest losses, maintains germination, and extends seed shelf life. This article discusses the scientific basis of seed longevity, physiological responses to storage conditions, and practical strategies for optimizing seed storage. It also highlights the importance of species-specific storage requirements and advances in storage technologies for preserving seed quality, supporting sustainable agriculture, and safeguarding germplasm for future breeding programs.

KEYWORDS: Relative humidity, seed longevity, seed storage, temperature, viability

INTRODUCTION

Crop production and plant biodiversity are based on seeds. Both commercial agriculture and germplasm conservation depend on their ability to remain viable over time. Genetic characteristics, moisture content, storage temperature, and relative humidity are some of the variables that affect seed longevity, or the amount of time that seeds maintain their ability to germinate. The rate of loss of vigour and viability of orthodox seeds depends mainly on the temperature where the seed is stored and the moisture content of the seed (Corbineau, F., 2024). Since temperature and relative humidity are the most controllable of these, they are essential tools for managing seed storage.

TEMPERATURE'S EFFECT ON SEED LONGEVITY

The metabolic rate of seeds is directly impacted by temperature. Lipid peroxidation, enzyme inactivation, and deterioration occur more quickly at higher temperatures because they speed up respiration and biochemical reactions. On the other hand, lower temperatures prolong seed viability by slowing these metabolic processes.

- Optimal storage temperatures vary by species but generally range from **0–15°C** for most orthodox seeds.
- Sub-zero storage (e.g., -18°C) is used for long-term conservation in seed banks.
- High temperatures, especially above 30°C, dramatically reduce seed longevity.

INFLUENCE OF RELATIVE HUMIDITY ON SEED STORAGE

The seed moisture content, which is directly related to physiological stability, is influenced by relative humidity. Seeds adjust to the relative humidity of their surroundings, and elevated relative humidity can lead to moisture absorption, which can encourage the growth of fungi, activate enzymes, and ultimately reduce germination, which deteriorates the seed and reducing the longevity. Seed aging causes internal DNA damage during storage that ultimately leads to viability decline (Waterworth *et al.*,2024) throughout the storage duration. Hence, seeds when stored in high relative humidity or moisture conditions age quickly, ultimately leading to less vigour seeds which fail to perform better under field conditions (Lohitha *et al*.,2024). But with proper management of relative humidity and moisture content of seeds during the storage period, seed quality can be maintained.

For orthodox seeds, a moisture content of 5–8% is ideal for long-term storage.

- Low RH environments (10–30%) reduce water activity, minimizing metabolic degradation.
- Moisture-proof packaging, desiccants, and humidity-controlled storage chambers are effective strategies.

Pic 1. Humidity-controlled storage chambers

INTERACTION BETWEEN TEMPERATURE AND RELATIVE HUMIDITY

Temperature and RH do not act independently. Their interaction determines the overall seed deterioration rate, commonly described by Harrington's "Seed Viability Equation", which states that every 1% decrease in seed moisture or 5°C decrease in storage temperature roughly doubles the seed's storage life (only applicable to orthodox seeds).

- **Cool and dry conditions** are universally optimal for orthodox seeds.
- **Tropical storage challenges:** High ambient temperatures and humidity require additional control measures like sealed containers, silica gel, or cold rooms.
- **Seed type considerations:** Recalcitrant seeds are sensitive to desiccation and cannot tolerate conventional low-moisture storage, requiring alternative approaches, rather like orthodox seeds.

TECHNIQUES FOR INCREASING THE LIFESPAN OF SEEDS

1. **Pre-storage Conditioning**: Make sure the seeds are thoroughly cleansed and dried.
2. **Moisture Control**: Make use of desiccants and packaging that can withstand moisture.
3. **Temperature Control**: Keep seeds at constant, low temperatures that are appropriate for their species.
4. **Consistent Monitoring**: Evaluate viability by testing germination rates on a regular basis.

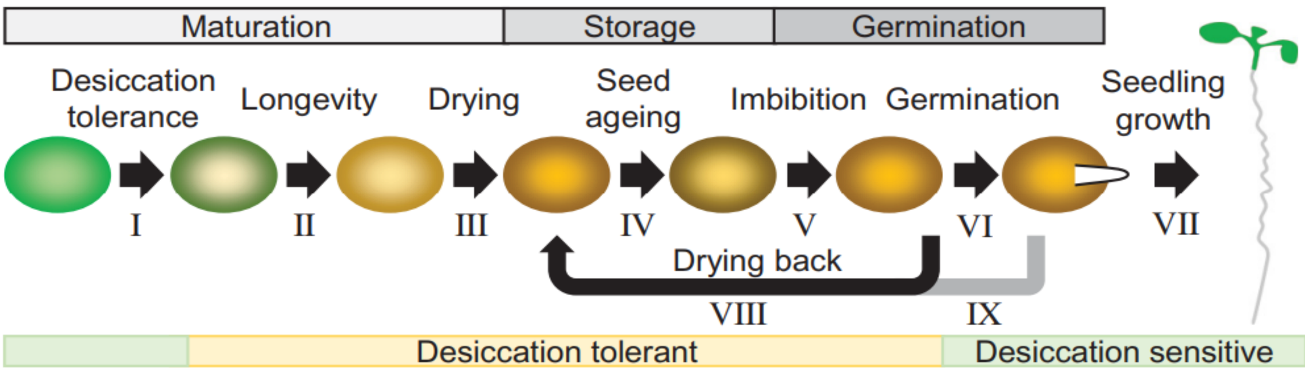

Figure 1: Series of stages showing how seed priming helps in improving seed longevity

(*taken from Wanda Waterworth et al.,2024)*

5. **Utilizing Controlled Atmospheres**: Storage that is vacuum-packed or nitrogen-flushed lessens oxidative damage.
6. **Seed Priming**: While some treatments can enhance storage performance, they must be carefully managed to prevent early deterioration.

Commercially seed priming technologies hydrate seeds first, following a dry back, to assist cellular repair and to improve the germination vigour and seedling growth (Fabrissin *et al*., 2021; Pagano *et al*.,2023). The figure below represents the important stages of seed from maturation to seedling establishment and how priming helps in improving longevity.

Here desiccation tolerance is lost as seeds progress to germination, but can be re-established by treatment with ABA or PEG (IX), allowing survival after re-drying (Zinsmeister *et al.*,2021).

CONCLUSION

Seed longevity is dependent on a complex interaction of genetic and environmental factors. The two most variable of them are temperature and relative humidity, making them crucial instruments for controlling seed storage. Adjusting moisture with the use of sealed containers, silica gel, or moisture-regulating chambers, and using crop-specific temperatures helps in increasing the seed longevity and reducing seed deterioration, thus preserving seed shelf life for a longer period of time. Along with these practices, research focused on preservation of germplasm in seed banks (long-term ageing) and stresses associated with short-term ageing, representing variable environmental conditions, should be given prime importance, which not only helps in improving seed longevity but also helps in maintaining the quality for a longer duration.

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