Vol. 3 Issue-5, January 2023 (e-ISSN: 2582-8223)

Ultra-dried Seed Storage- Advanced Technology to Extend Seed Longevity

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ARTICLE ID: 85

Introduction

Seed storage has been proposed as one of the most practical conservation methods for ensuring the long-term survival of endangered species. As per Harrington thumb rule of seed storage, lifespan of seed can be enhanced considerably by lowering both moisture and temperature. However, moisture content is the key factor that can be lowered for successful seed storage. Cold storage is expensive and difficult to maintain because electricity supplies are often inconsistent and unreliable. Furthermore, seeds that have been dried to a low moisture content are more tolerant to storage at high temperatures. Even prolonged sun drying in high humidity, however, cannot reduce seed moisture content to levels sufficient to ensure long-term viability. These issues can be resolved by ultra-drying seeds. In specifically, ultra-dry seed storage involves reducing seed moisture content (MC) to an ideal level (below 5- 6 %) using different methods for secure long-term storage then stored hermetically at ambient, but preferably cooler temperatures. Such methods provide long-term seed storage without compromising the integrity of cellular membrane structure and seed functions. The maintenance of seed viability, tissue and cell morphological integrity, and genetic material stability may be possible with the use of ultra-dry storage technologies in agriculture and forestry (Wawrzyniak et al., 2020). Indeed, ultra-day seed storage is easier, more straightforward, and more ecologically friendly when compared to conventional refrigeration techniques. As a result, many seed species are currently stored using ultra-dry storage. Oily seeds, in particular, such as *Brassica napus*, *Sesamum indicum*, and *Arachis hypogea* seeds, are resistant to dry storage due to their hydrophobic properties (Mira et al., 2019). Thus, ultra-dry seed storage technology is one of the best ways to store seeds for a longer period of time by using desiccants in an airtight container without destroying seed quality. As a result, it is an appropriate technology for low volume seeds, seed companies, and seed banks to store valuable seed material for a longer period of time.

Methods of ultra-drying

1. **Dry room or drying chamber/cabinet**

An airlock should be installed in drying rooms to reduce moisture entry from the outside. Any species of seed, at any moisture content, will dry in roughly 30 days in a normal dry room set at 10-15% RH and 10-25°C.

2. Desiccants

The drying time (one month) is determined by the initial moisture content of the seeds, the quantity of seeds, and the dryness of the desiccant. A desiccant is a hygroscopic material that causes or maintains desiccation (dryness) in its close vicinity. Commonly pre-packaged desiccants are solids that absorb water. Desiccants are frequently employed in industry to regulate the amount of water in gas streams. The most commonly used desiccants are Silica gel, Activated charcoal, Bentonite and Beads (Zeolites).

3. Saturated salts / Lithium Chloride solutions

Lithium chloride creates a relative humidity (RH) of around 12% At 20 °C. At 25 °C, calcium chloride produces a RH of about 30%. Lithium chloride solution in an airtight jar with a plastic mesh support holding the seeds above the solution. Only plastic-coated metal components should be used as salts may be very corrosive.

4. Vacuum freeze drying

Freeze the material below the eutectic point temperature first, causing the water to solidify into ice. Subsequently, under the proper vacuum, the ice directly sublimates to water vapourand then use the water vapor condenser in the vacuum system to condense the water vapor, so as to obtain the drying. It can quickly remove water and handle large quantities of seeds. The effect is significant within 24 hours and its effect is slight after long time. It is suitable for treating oilseeds and small seeds, but the effect on protein and starch seeds is limited.

5. Heat drying

It is a method for removing moisture from seeds that relies on heating. Convective heat transfer occurs when heated hot gases or smoke fumes from fuel combustion transmit heat to the seeds. some studies showed that heat drying might damage seeds.

Physiological and biochemical basis of ultra-dry storage seeds

Effect of ultra-drying on cell structure

The structural integrity of cells is the fundamental basis of seed vigour. Seed vigour began to decline as storage time increased, as showed cell membrane structure damage, organelle and genetic material distortion and disintegration, a large number of storage materials exosmosis, and various enzyme activities. The arrangement of phospholipids on the cell membrane changed as the water content of seeds decreased, and the continuous interface of the membrane could not be maintained. When the water content of seeds falls below a certain level, phospholipids and protein molecules turn away due to a loss of water film protection, and the membrane's continuous interface is destroyed. The osmoregulation function is lost as the membrane transitions from the mobile phase to the gel phase. findings demonstrated that although the cell shape was preserved, the surface cells of super-dried seed cotyledons were contractile. The nuclear membrane is blurry, the endoplasmic reticulum is enlarged, and the cell's bilayer membrane structure is not visible. It can be seen that the internal structure of seeds was not harmed and the anti-aging performance of seeds was enhanced by ultra-dry treatment with moderate water content.

Effects of ultra-dry storage on antioxidant enzyme and membrane peroxidation System

Membrane peroxidation produces many potentially toxicants during seed ageing, including free radicals, superoxide radicals, and malondialdehyde. Free radicals have the ability to destroy the membrane system of macromolecule polymers and cells, resulting in a series of complex chain reactions that eventually lead to seed deterioration and seed vigour decline. Zhao et al. (2009) discovered that the content of oxygen free radicals and malondialdehyde increased less in ultra-dry soybean seeds than in non-ultra-dry soybean seeds, and that the scavenging ability of oxygen free radicals in ultra-dry ageing soybean seeds was greater than in non-ultra-dry ageing soybean seeds. Zhu et al., (2007) discovered that moderate drying inhibited lipid peroxidation directly or indirectly, whereas excessive drying promoted lipid peroxidation to some extent. According to some studies, the vigour of Ultra-dry seeds was significantly higher than that of non-ultra-dry seeds, and the maintenance of high-vigor seeds was related to the integrity of the free radical scavenging system. Zhao et al. (2009) discovered a relationship between the high antioxidant enzyme system (superoxide Dismutase, Peroxidase, Catalase) content of ultra-dried seeds and their potent anti-aging properties. In embryos and cotyledons of ultra-dried seeds, superoxide Dismutase (SOD), Peroxidase (POD), Catalase (CAT) activity declines were less pronounced than in non-ultra-dried seeds. Duan et al. (2008) compared the vigour of celery seeds after ultra-dry storage versus conventional storage. The activities of SOD, POD, and CAT in Ultra-dry Storage celery seeds were found to be higher than in conventional storage seeds, indicating that ultra-dry treatment was beneficial in removing harmful substances produced during storage and improving seed storage resistance. The ability of ultra-dry seeds to withstand storage conditions may be due to a synergistic interaction between the benefits of maintaining a high-quality free radical scavenging system and the damaging effects of peroxidation that are increased by ultra-dry seeds. There is still need for more research into the ideal moisture level for seeds to be stored under ultra-dry conditions.

Effects of Ultra-dry storage on germination and vigor

The effect of ultra-dry storage on seed vigour, tissue and cell morphology, and genetic material stability is dependent on seed storage tolerance and storage environment conditions. Even for storage-tolerant seeds, ultra-dry treatment may cause water to enter the seed quickly in response to a low water potential during seed germination (Ballesteros *et al.*, 2011), causing cell membrane damage and solute leakage into the apoplast (Bewley *et al.*, 2013). It is possible to reduce or eliminate such damage through proper osmotic adjustment and gradual priming prior to germination, such as natural priming, PEG priming, or saturation water vapour priming, which can improve the quality parameters of ageing seeds, such as the germination rate and vigour (Jisha*et al.*,2013). furthermore, priming may even restore the original germination rate (Murthy *et al.*, 2003). The ultra-dry treatment increased seedling growth and germination capacity (Xie*et al.*, 2021). Ultra-dry storage appears to provide a method of reducing or eliminating the damage caused by seed priming, which regulates the extent of cell water absorption and hydration status, thus stabilizing and harmonizing water absorption by seeds and resulting in successful seedling development. Seedling growth, photosynthesis, and respiratory rate were reportedly improved by ultra-dry storage in oil, starch and some protein-rich seeds. Seed MC rapidly decreases during the ultra-drying process, resulting in a series of physiological changes within the seeds that may cause dehydration stress. This dehydration stress is maintained during storage and stimulates an increase in protective enzyme activity and protective substance content; however, once the seed reaches a certain level of dehydration, the protective substance content decreases (Walters, 2015). Nonetheless, proper priming can maintain cell membrane structure and function in the seed, reducing seed damage, most likely by removing harmful substances generated during germination and repairing cell structure (Xia *et al.*, 2016). All of these processes necessitate the involvement of antioxidant enzymes, the levels of which rise during germination (Demir *et al.*, 2007).

Conclusion

Ultra-dry seed storage technology is one of the best ways to store seeds for a longer period of time by using desiccants in an airtight container without loosing seed quality. As a result, it is an appropriate technology for low volume seeds, seed companies, and seed banks to store valuable seed material for a longer period of time.

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