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Comparing seed conservation technologies for banking different seed propagules: IBRC seed bank as a successful model

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Introduction: Plant genetic resources are essential for biodiversity and agriculture but face threats like habitat destruction and climate change. This paper compares seed banking strategies at the Iranian Biological Resource Center (IBRC) for conserving 14,000 plant samples, focusing on methods, benefits, and challenges, especially for different seed propagules.

Materials and methods: Different seed propagules are qualitatively compared regarding their responses to different conservation methods, including refrigeration at +4° C, freezing at -18° C to -20° C, and cryobanking at -196° C, and then analysed their respective advantages and disadvantages. Seed banking process, encompassing steps of collecting, cleaning, testing, storing, packaging, and regular monitoring is also explored (Fig. 1).

Results and Discussion:

Seed propagules are classified as orthodox, intermediate, or recalcitrant based on their freezing response, affecting viability and storage. Orthodox seeds (representing 75-80% of angiosperm species) tolerate dehydration and low temperatures, ideal for long-term storage. Intermediate seeds need specific conditions, while recalcitrant seeds (comprising 5-10% of angiosperms), found in tropical regions, require cryopreservation techniques due to their intolerance to drying and freezing. Studies show varying responses among recalcitrant seeds to cryopreservation. For instance, *Citrus macroptera* exhibited high desiccation and freezing tolerance, with a recovery rate of 87% using air desiccation-freezing (Malik & Chaudhury, 2006).

Seed banking strategies use various methods to preserve seed viability long-term, depending on seed type and storage duration. **Short-term storage** at 4°C (Active Collection) suits seeds with intermediate longevity, while **long-term storage** (Base Collection) at -18°C to -20°C is ideal for orthodox seeds. **Cryopreservation** at -196°C is necessary for recalcitrant seeds. Each method has specific requirements and challenges, including cost and technical expertise (Malik & Chaudhury, 2006; Aryakia et al., 2012) (Table 1).

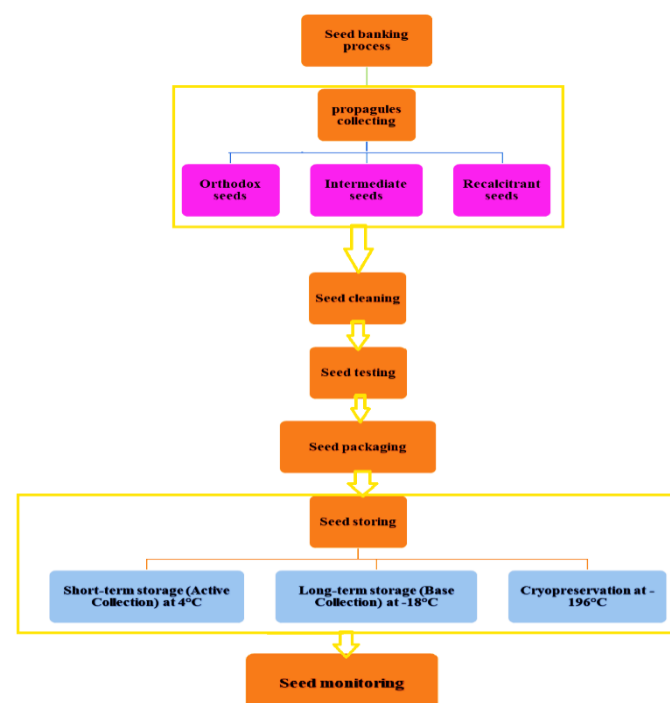

Figure 1: Seed banking process at IBRC

Seed banking process involves several critical steps to ensure the long-term preservation of seeds. Initially, **seed collection** targets a broad genetic diversity, focusing on endangered or agriculturally important species. Seeds are gathered at optimal maturity stages and with adherence to ethical guidelines, ensuring minimal impact on wild populations. Following collection, **seed cleaning** removes impurities and damaged seeds, ensuring the purity and viability of stored seeds. Mechanical and manual cleaning methods are employed to prevent contamination and preserve seed longevity. **Seed testing** further ensures the viability and purity of the seeds before storage, with germination and moisture content analyses conducted according to established guidelines like those of ISTA. Proper **seed storage** is crucial, involving low temperatures and controlled humidity to slow metabolic processes and prevent deterioration. Storage facilities must maintain stable conditions, with seeds kept in sealed containers to prevent environmental fluctuations. **Regular monitoring** is essential to assess seed viability and detect any signs of deterioration, guiding decisions on seed regeneration or replacement (Ballesteros et al. 2021; Aryakia et al., 2012; Martyn et al., 2009).

Table 1: Comparing seed conservation technologies for banking different seed propagules

Aspect	Orthodox Seeds	Intermediate Seeds	Recalcitrant Seeds
Definition	Seeds that tolerate drying and freezing	Seeds with moderate tolerance to drying and freezing	Seeds sensitive to drying and freezing
Example Species	Wheat, rice, barley	Coffee, papaya, citrus	Mango, avocado, coconut
Optimal Storage Method	Cool to Low-temperature storage (-18°C to -20°C)	Cool storage (+4°C)	Cryopreservation (-196°C)
Longevity	Long-term (decades to centuries)	Medium-term (years to decades)	Short-term (months to few years without cryopreservation)
Viability after Storage	High when stored properly	Moderate, requires specific conditions	Low without cryopreservation; high with cryopreservation
Cost of Storage	Low to moderate	Moderate	High
Technical Expertise Required	Low to moderate	Moderate	High (due to cryopreservation techniques)
Challenges	Minimal aging, requires periodic monitoring	Sensitive to moisture and temperature fluctuations	Difficult to store without advanced techniques; high cost and expertise
Examples of Storage Facilities	Seed banks, such as the IBRC and Svalbard Global Seed Vault	National and regional seed banks such as IBRC	Specialized cryopreservation facilities like IBRC
Applications	Suitable for global conservation efforts	Suitable for species with moderate longevity	Essential for tropical species and those with recalcitrant seeds

Conclusion: Seed banking represents a cornerstone of global conservation efforts. The comparison of various seed propagules—orthodox, intermediate, and recalcitrant—highlights the nuanced approach required for effective long-term storage. Orthodox seeds, with their natural resilience to dehydration and low temperatures, are best suited for traditional cold storage methods, offering a practical and cost-effective solution for most species. Intermediate seeds demand more specialized conditions, balancing between drying tolerance and sensitivity to freezing, while recalcitrant seeds, often from tropical regions, challenge conventional storage methods and necessitate advanced cryopreservation techniques. The intricate seed banking process—from collection and cleaning to testing, storage, and monitoring—demonstrates the need for meticulous planning and execution to maintain seed viability. Regular monitoring and appropriate storage conditions are critical in preventing deterioration and ensuring the longevity of these genetic resources. While cryopreservation emerges as the most secure method for recalcitrant seeds, it also underscores the complexity and cost of preserving the most vulnerable species. Ultimately, seed banking is not just a technical endeavor but a strategic response to the urgent need for biodiversity conservation. As global challenges like climate change and habitat loss intensify, the role of seed banks becomes ever more crucial, safeguarding the genetic diversity that underpins our agricultural and ecological future.

Keywords: Conservation, Cryopreservation, Orthodox, Recalcitrant, Seed banking

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