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The significance of seed banks: A review of techniques and technologies

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Abstract

In order to preserve the genetic diversity of plant species, seed banks are essential organizations for the conservation of plant biodiversity. They serve as a buffer against extinction brought on by habitat loss, climate change, and environmental changes by storing seeds of both wild and domesticated plants. The idea of seed banks is examined in this review study along with their varieties, operational procedures, and obstacles, such as seed viability, resource scarcity, contamination hazards, and the effects of climate change. It also emphasizes how crucial seed banks are to preserving biodiversity, assisting with ecological restoration initiatives, and guaranteeing food security. Future directions for seed bank development are also covered in the report, with an emphasis on the necessity of better technology, international cooperation, and including local populations in conservation initiatives. To sum up, seed banks are essential to the long-term conservation of biodiversity, and resolving present issues will guarantee their continuous efficacy in protecting plant species for coming generations.

Keywords: Seed Bank; Seed Storage Techniques; Seed Viability; Plant Biodiversity; Endangered Plant Species; Seed Bank Management

1. Introduction

In view of the mounting threats faced by habitat loss, climate change, and human-induced environmental degradation, seed banks are essential to the conservation of plant species. In order to maintain their genetic diversity and guarantee their continued availability, these facilities are made to store seeds from a broad range of plant species, including uncommon, endangered, and agriculturally significant species (Smith et al., 2017). As a preventative measure against extinction and a crucial resource for ecosystem restoration, food security, and sustainable farming methods, seed banks' main goal is to preserve plant genetic resources for future generations (Lal, 2015).

In order to keep seeds viable for extended periods of time, seed banks gather seeds—often in collaboration with governments, conservation groups, and academic institutions—and store them in controlled environments with low humidity and low temperatures (FAO, 2010). Research on plant genetics and breeding, agriculture development, and ecosystem restoration are just a few uses for the stored seeds (Meyer & O'Connell, 2004). Seed banks help to lessen the effects of biodiversity loss and preserve genetic material while also offering vital resources for scientific research (National Seed Bank, 2021).

The creation and upkeep of seed banks have been the subject of several national and international initiatives worldwide; institutions such as the Global Seed Vault in Svalbard, Norway, are an important example of an international endeavor to guarantee the preservation of plant diversity worldwide (Smith et al., 2017). But there are still issues with guaranteeing the long-term viability and efficacy of seed banks, particularly in view of new dangers like climate change that could have an impact on plant germination and seed viability (Lal, 2015).

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2. Types of Seed Banks

Seed banks are classified based on their objectives, target species, and methods of preservation. Below are the main types of seed banks:

2.1. Conservation Seed Banks

The main goal of conservation seed banks is to preserve seeds from wild plant species, particularly those that are rare, endangered, or vulnerable. By conserving genetic material that might be in danger of going extinct as a result of habitat loss, climate change, overexploitation, or other ecological concerns, these seed banks aim to preserve biodiversity. In order to assist with ecosystem restoration initiatives, conservation seed banks also strive to maintain the genetic variety of native plant species.

These seed banks are crucial to the preservation of wild species, including those that inhabit marshes, forests, grasslands, and natural environments. Ensuring the long-term survival of plant species is the main objective, particularly for those with restricted ranges or those that are in danger of going extinct. They might collaborate with groups like Botanic Gardens Conservation International (BGCI) and the World Wildlife Fund (WWF). *The Millennium Seed Bank* in the UK, one of the largest and most important conservation seed banks, aims to collect and store seeds from plants around the world, particularly those that are rare or endangered (Meyer & O'Connell, 2004).

2.2. Germplasm Seed Banks

The preservation of seeds from agricultural crops and their wild cousins is the main goal of germplasm seed banks. In order to increase crops' resistance to pests, diseases, and climate stressors, it is imperative that these seed banks preserve the genetic variety of the crops used in agriculture. Both conventional and contemporary crop types are kept in germplasm banks, guaranteeing the preservation of important genetic features for upcoming breeding initiatives and food security.

The creation of novel crop types that can resist environmental stresses like heat or drought depends on the genetic resources kept in these seed banks. Furthermore, by preserving the variety of food crops, germplasm seed banks guarantee a steady supply of vital nutrients.

The International Rice Gene Bank in the Philippines is an example of a germplasm bank that focuses on preserving rice varieties to ensure food security and enhance global rice production.

2.3. Commercial Seed Banks

The main objective of commercial seed banks is to store seeds for agricultural production, frequently in order to guarantee dependable and effective seed production for the market. Usually, high-yielding crop kinds' seeds are kept in these banks for agricultural use. Commercial seed banks collaborate closely with agricultural businesses, and their collections assist seed trade and commerce while also saving seeds for future use.

Commercial seed banks are crucial in guaranteeing that farmers have access to superior, genetically varied seeds that are resilient to a range of environmental stressors, even though their primary aim is not conservation or biodiversity.

Monsanto's Seed Vault serves as a commercial facility storing genetically modified and hybrid *seeds* for agricultural use and crop production.

2.4. Global and Regional Seed Banks

Global and regional seed banks are sizable establishments created to gather and preserve seeds from a broad range of plant species worldwide, usually with a focus on agricultural sustainability and biodiversity preservation. These banks frequently concentrate on developing a thorough contingency plan for plant genetic resources to guard against regional or worldwide calamities that can jeopardize biodiversity or food security.

As a safeguard against world crises, global seed banks act as international repositories that gather seeds from numerous nations. To preserve local biodiversity, regional seed banks, on the other hand, concentrate on gathering seeds from species unique to a given geographic area.

The Svalbard Global Seed Vault in Norway, often referred to as the "Doomsday Vault," is a global seed bank designed to safeguard plant genetic resources for future generations in the event of global disasters (*Smith* et al., 2017).

2.5. Cryopreservation Seed Banks

To keep seeds, plant tissues, or embryos dormant, cryopreservation seed banks employ extremely low temperatures, frequently in liquid nitrogen. For species whose seeds are challenging to preserve using conventional techniques or for those that need longer-term preservation than what conventional seed banks can offer, this preservation technique is especially helpful. The process of cryopreservation aids in the long-term storage of plant species, especially those having seeds that are difficult to dry out and freeze. Traditional seed storage methods are increasingly being supplemented by cryopreservation procedures.

The **National Center for Genetic Resources Preservation (NCGRP)** in the United States uses cryopreservation to preserve a range of species, including those with recalcitrant seeds and plant tissues (Dawson et al., 2015).

3. Methods of Seed Banks

Seed banks use various methods to collect, preserve, and store seeds for long-term viability:

3.1. Seed Collection:

Seeds from significant crop species, endangered species, or wild plants are meticulously gathered. The species, collecting location, and conditions are all properly documented.

3.2. Seed Cleaning and Drying:

To stop fungus or microbiological growth, seeds are cleaned to get rid of dirt and dried to lower their moisture content (usually 5-8%).

3.3. Seed Storage Methods

Seeds are kept in freezers or refrigerators with temperatures between 0°C and -20°C.

3.4. Cryopreservation

Particularly for stubborn seeds that cannot withstand drying, seeds are kept in liquid nitrogen at extremely low temperatures (around -196°C) (Dawson et al., 2015).

3.5. Desiccation

Conventional seeds are typically dried to low moisture content and then stored in airtight containers.

3.6. Seed Viability Testing

The seeds' continued viability is guaranteed by routine germination testing. Seed quality can be evaluated using additional assays, such as conductivity or tetrazolium testing.

3.7. Regeneration and Exchange

Seed banks use saved seeds to create new plants, regenerating collections. Bank-to-bank seed exchange initiatives contribute to the preservation of genetic diversity worldwide.

3.8. Documentation

Seed collections are tracked using comprehensive databases that contain data on species, origin, viability, and storage conditions.

4. Importance of Seed Banks

Seed banks are vital for preserving plant genetic diversity, supporting agriculture, and ensuring the resilience of ecosystems. Their importance can be highlighted in several key areas

4.1. Preserving Genetic Diversity

The genetic material of plant species, especially uncommon, endangered, and economically significant species, is preserved by seed banks. In the face of concerns like habitat loss and climate change, this preservation is essential for preserving biodiversity and facilitating future restoration initiatives.

4.2. Ensuring Food Security

Seed banks protect agricultural biodiversity by preserving seeds of a variety of crops, including traditional and heirloom types. This makes it possible to reintroduce hardy crop varieties, which helps guarantee food supplies, particularly in the face of changing climates and environmental stressors.

4.3. Supporting Ecosystem Restoration

Because they provide seeds for replanting in damaged or degraded ecosystems, seed banks are essential to ecosystem restoration. This aids in the restoration of equilibrium in impacted environments and the regeneration of biodiversity.

4.4. Mitigating Climate Change Impact

Plant genetic resources that could be essential for adjusting crops to different climate conditions are preserved in seed banks. They supply the genetic material required to create crops that are resilient to the effects of climate change, including extremes in temperature, drought, and flooding.

4.5. Protecting Against Invasive Species

When invasive species endanger native plant species, seed banks provide a fallback option so that the plants can be returned to their natural habitats if needed.

5. Challenges Facing Seed Banks

5.1. Seed Viability and Longevity

One of the biggest challenges is making sure seeds stay viable for extended periods of time. Certain species have a short storage life, particularly those with refractory seeds (those that cannot withstand drying or freezing). Maintaining seed viability, even for conventional seeds, calls for routine observation and resupply.

5.2. Limited Resources and Space

Smaller seed banks in particular frequently struggle with space and budget limitations that restrict their capacity to hold huge numbers of seeds. Numerous species require expensive maintenance and management, as well as related infrastructure like temperature-controlled storage**.**

5.3. Climate Change

Because climate change affects storage conditions like humidity and temperature, seed bank collections are at danger. These changes in the environment might impact the viability of seeds and make long-term storage procedures more difficult.

5.4. Genetic Erosion

Genetic degradation may result from the fact that many seed banks do not accurately reflect a species' genetic diversity. This can lessen the efficacy of restoration efforts when just a small number of samples are saved, leaving out significant genetic features.

5.5. Contamination Risks

In order to prevent stored seeds from being compromised, seed banks must protect themselves from contamination by pests, diseases, and other outside influences. Such contamination has the potential to destroy entire collections if it is not controlled.

5.6. Access and Equity Issues

Many areas, particularly in developing nations, lack the infrastructure and resources necessary to profit from seed bank collections, making access to seed banks inequitable. Fair distribution and local communities' rights are called into question by this.

6. Future Directions for Seed Bank Development

6.1. Advancing Technologies

Using cutting-edge methods like genetic engineering, biotechnology, and cryopreservation can increase seed viability and storage duration.

6.2. Expanding Seed Collections

concentrating on protecting genetic variety, wild vegetation, and more underrepresented species in order to mitigate the threats posed by climate change and environmental degradation**.**

6.3. Global Collaboration

Bolstering international seed bank networks to exchange information and resources, guaranteeing a better-coordinated strategy for biodiversity preservation**.**

6.4. Involvement in Ecosystem Restoration

By supplying seeds for native plants and aiding in habitat recovery, seed banks ought to be essential to the restoration of ecosystems.

6.5. Climate Change Adaptation

To assist ecosystems in adapting to changing conditions, prioritize the preservation of species that are climate resilient, such as plants that can withstand heat and drought.

6.6. Community Engagement

To raise public awareness and support regional conservation projects, involve local communities and citizen scientists in seed collection and conservation activities.

7. Conclusion

As a defense against habitat loss, species extinction, and the consequences of climate change, seed banks are vital resources for maintaining plant biodiversity. They are essential for maintaining agricultural resilience, guaranteeing the supply of seeds for restoration initiatives, and preserving genetic variety. Notwithstanding the many obstacles, including the influence of climate change, scarce resources, and seed viability, seed banks have made great progress in developing technologies and growing their collections to address these issues. Future initiatives must concentrate on enhancing seed preservation techniques, encouraging international collaboration, and guaranteeing wider community involvement in order to increase the efficacy of seed banks. To ensure that biodiversity is conserved for future generations, the ongoing development of seed banks will necessitate a cooperative approach that integrates developments in biotechnology, ecosystem restoration, and climate adaption. To sum up, seed banks are an essential part of international conservation plans. They will continue to offer priceless resources for preserving the planet's plant diversity, promoting agricultural security, and aiding ecological restoration initiatives globally with sustained investment, innovation, and international cooperation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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