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PERMAFROST SEED CONSERVATION

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Abstract

Permafrost-based seed conservation is an important strategy for long-term ex situ preservation, where naturally frozen ground is used to safeguard plant genetic resources. Seeds are stored at sub-zero temperatures and very low moisture levels, which suppress metabolic processes and greatly extend seed lifespan. A key advantage of this method is its dependence on naturally stable permafrost conditions, reducing the need for continuous artificial refrigeration and lowering energy consumption. Such facilities mainly serve as safety back-up repositories for base collections maintained in national and international gene banks, providing protection against accidental or irreversible loss. Well-known examples include the Svalbard Global Seed Vault and the Indian Seed Vault. Collectively, these vaults strengthen global genetic security by shielding crop diversity from risks such as natural calamities, armed conflicts, technical failures, and institutional breakdowns. In this way, permafrost seed conservation acts as a global insurance mechanism, ensuring the long-term survival of vital crop diversity for centuries.

Keywords: Permafrost seed conservation, Svalbard Global Seed Vault, Indian Seed Vault, Doomsday Seed Vault, Ex-Situ Conservation.

Permafrost seed conservation

Permafrost seed conservation is a method of long-term ex-situ conservation in which seeds are stored in naturally frozen ground (permafrost regions) at sub-zero temperatures, ensuring minimal metabolic activity and maximum longevity of seeds. It is mainly used for safety duplication of base collections maintained in national and international seed gene banks. In permafrost seed conservation, the seeds are stored at low temperature and low seed moisture content. Permafrost environments provide stable, naturally cold conditions, reducing the dependence on artificial cooling systems.

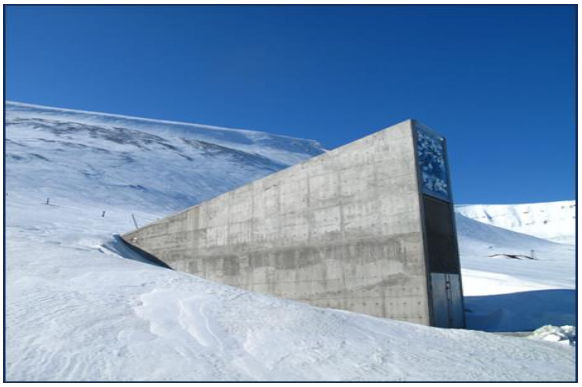
The most prominent examples of permafrost seed conservation are the Svalbard Global Seed Vault, located on the Arctic island of Spitsbergen, Norway and the Indian Seed Vault, located at Chang La, Ladakh.

Svalbard Global Seed Vault (Doomsday Seed Vault)

- The Svalbard Global Seed Vault serves a humanitarian role within the international system for conserving plant genetic resources under the guidance of the Food and Agriculture Organization (FAO).
- It provides secure, cost-free, and long-term back-up storage for duplicate seed samples originating from gene banks across the world, supporting global efforts to protect future food security.
- The facility, carved deep into solid rock, was opened on 26 February 2008. The seed storage chambers are located over 100 meters inside a mountain and protected by 40–60 meters of rock. Seeds are conserved under "black box

conditions," meaning access is restricted to depositors.

- The surrounding mountain contains natural permafrost, maintaining a stable ambient temperature of around −3 to −4°C. To further enhance seed longevity, an artificial cooling system lowers and stabilizes the storage temperature at −18°C. Power to the vault is supplied by the public electricity network in Longyearbyen, and backup generators ensure uninterrupted operation during power failures.
- The vault contains three storage halls, each measuring about 9.5 × 27 meters and capable of holding 1.5 million seed accessions, giving a total capacity of 4.5 million samples. Currently, one hall is in use, housing 1,378,238 seed samples representing 6,521 species from 131 depositors; additional halls will be activated as needed.
- Major crops conserved include wheat and rice (over 150,000 samples each), barley (about 80,000), sorghum, beans (*Phaseolus*), maize, cowpea, soybean, chickpea, kikuyu grass, and several others such as potato, groundnut, oats, rye, alfalfa, *Tritikosecale*, and *Brassica* species.
- Around two-thirds of the accessions originate from CGIAR research centres, notably CIMMYT, IRRI, ICARDA, ICRISAT, and CIAT. National gene banks from the USA, Germany, Canada, and the Netherlands are major contributors, while NordGen serves as the principal regional depositor for the Nordic countries.
- In India, base collections of plant genetic resources are maintained at the ICAR–National Bureau of Plant Genetic Resources (NBPGR), New Delhi. As part of international safety duplication initiatives, duplicate samples of valuable Indian germplasm are also deposited in the Svalbard Global Seed Vault.

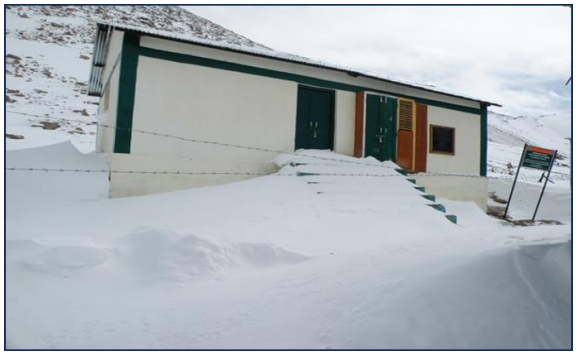


Svalbard Global Seed Vault and Storage facility in Svalbard Global Seed Vault

Indian Seed Vault

- The Indian Seed Vault is a high-altitude seed conservation facility situated at Chang La in Ladakh, at an elevation exceeding 17,000 feet. It was established in 2010 through a joint initiative of the Defence Institute of High-Altitude Research and the National Bureau of Plant Genetic Resources, functioning under the Defence Research and Development Organisation. The facility is recognized as the second-largest seed bank globally.

- By 2025, the vault conserves more than 5,000 seed accessions representing distinct crop varieties, populations, and geographic origins. Emphasis is placed on stress-tolerant vegetable crops such as apricot, cabbage, carrot, potato, and radish, along with major food crops including barley, pea, rice, and wheat.
- Seeds are sealed in three-layer aluminium foil packets to ensure long-term protection and are selected for superior yield potential, resistance to pests, and suitability for extreme environments.



Indian Seed Vault

Advantages of permafrost seed conservation

- Extremely long-term storage (hundreds of years)
- Minimal energy requirement
- High level of genetic security
- Protection against: natural disasters, wars and conflicts; equipment failure
- Acts as a global insurance policy for crop diversity

Conclusion

Permafrost seed vaults represent one of the most resilient and sustainable approaches to conserving global plant genetic resources. By using naturally cold environments, facilities such as the Svalbard Global Seed Vault and the Indian Seed Vault at Chang La enable ultra-long-term storage with minimal energy input while securely safeguarding duplicate germplasm collections. Acting as a global insurance mechanism, these vaults protect crop diversity from technical failures, natural disasters, and geopolitical conflicts, thereby providing the highest level of genetic security and ensuring the survival of vital agricultural species for future generations.