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## Modern Seed Storage Methods that Preserve Traditional Seeds

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Traditional seeds are open-pollinated seeds that farmers have carefully selected, preserved and resown generation after generation. These seeds have developed, over centuries, a distinctive capacity to adapt to local climate, soil type, and environmental conditions. They are not merely instruments of agricultural production rather, they stand as living evidence of each community's traditional knowledge, cultural identity and food sovereignty. The genetic resources embedded within them are considered one of the most crucial safeguards for global food security. However, since the mid-twentieth century Green Revolution and the commercial agricultural transformations that followed it, the Food and Agriculture Organization of the United Nations estimates that up to 75 percent of the world's crop varieties have been lost. Against this backdrop, examining modern seed-storage methods has become an essential and urgent need. It represents the erosion of thousands of years of accumulated agro-ecological knowledge. Every landrace variety that disappears takes with it a unique combination of genes that evolved in response to a specific local environment a particular soil chemistry, a particular rainfall pattern, a particular set of local pests and diseases. Once that combination is lost, it cannot be recreated by breeding programs, no matter how sophisticated, because the exact evolutionary pathway that produced it decades or centuries of farmer selection under specific local pressures cannot be replayed. This is why the preservation of traditional seeds is often described as a race against time.

### The Importance of Traditional Seeds

The importance of traditional seeds must be approached from multiple angles. They play a critical role at the biological, ecological, social, and economic levels alike.

#### Biological Diversity and Genetic Resources

Shaped over centuries through both natural selection and human selection, traditional seeds carry a distinctive genetic architecture. This genetic resource naturally carries traits such as disease resistance, drought tolerance, and pest resistance. This genetic diversity functions as a kind of insurance policy for agriculture. Modern high-yielding hybrid varieties are often bred from a narrow genetic base, which makes them vulnerable to new pests, diseases, or climatic stresses that were not anticipated at the time of breeding. Traditional varieties, by contrast, carry a far wider range of genetic variation, some of which may hold the key to resistance against threats that have not yet emerged. Plant breeders regularly return to traditional and wild relative varieties to find genes for disease resistance that can then be bred into modern commercial varieties a process that depends entirely on traditional seed diversity still being available to draw upon.

#### Nutritional Superiority

Numerous studies have demonstrated that, compared with hybrid seeds, traditional seeds contain higher levels of micronutrients, vitamins, and distinctive flavour compounds. One study found that certain traditional rice varieties contained 30–40% more iron and zinc than modern varieties. This nutritional dimension has taken on renewed significance in recent years as public health researchers have drawn attention to "hidden hunger" micronutrient deficiencies that persist even where calorie intake is adequate. Because many modern high-

yield varieties were bred primarily to maximize yield and shelf life rather than nutrient density, the loss of nutrient rich traditional varieties may be contributing, in some regions, to a decline in dietary micronutrient intake even as overall food production rises. Traditional varieties also frequently carry distinctive taste, aroma, and cooking qualities that are prized in regional cuisines and that are often lost when a crop is bred purely for yield and transportability.

### **Ecological Contribution**

The cultivation of traditional seeds improves soil fertility, reduces water requirements, and lowers dependence on chemical inputs. They provide the practical foundation for ecologically sustainable agriculture. Traditional varieties are typically grown using low-input, mixed-cropping, or rotational systems that support beneficial soil organisms, reduce erosion, and maintain long-term soil structure. Because many traditional varieties evolved without the expectation of heavy chemical fertilizer or pesticide use, they often possess an inherent hardiness that allows them to perform reasonably well even under input-poor conditions a crucial trait for smallholder farmers who cannot afford expensive agrochemicals. In addition, traditional intercropping systems built around heirloom varieties tend to support greater on-farm biodiversity, including pollinators and natural predators of crop pests, than the large monoculture blocks associated with modern commercial hybrids.

### **Cultural and Social Value**

Beyond biology and ecology, traditional seeds carry deep social meaning. Varieties are often tied to specific festivals, rituals, recipes, or regional identities; the act of seed-saving itself is frequently embedded in social relationships, as seeds are exchanged, gifted, and inherited within families and communities. When a traditional variety disappears, the community also loses the stories, farming calendars, and culinary practices that were built around it. This is why seed preservation efforts increasingly emphasize not just storing the physical seed but documenting the associated agricultural and cultural knowledge as well.

### **Reasons for the Decline of Traditional Seeds**

The decline of traditional seeds does not stem from a single cause; rather, it arises from the cumulative effect of a range of social, economic, and technological factors.

#### **Key Factors**

- The rapid commercialization of hybrid and genetically modified seeds
- Chemical-input-based, compulsory monoculture cropping systems
- Migration of rural populations to urban areas and a shrinking number of farmers
- Absence of formal recognition for traditional seeds within national seed policies
- Yield losses caused by climate change and extreme weather events
- Failure to pass traditional agricultural knowledge onto younger generations

Each of these factors reinforces the others. For example, as fewer young people remain in farming, there are fewer hands available to carry out the labour-intensive practices of seed selection, drying, and storage that traditional seed-saving requires practices that are often more time-consuming than simply purchasing certified hybrid seed each season. Meanwhile, seed-certification and marketing systems in many countries are structured around registered hybrid and modified varieties, so traditional varieties frequently cannot be legally sold as certified seed, further discouraging their commercial cultivation. Climate change adds another layer of pressure: unpredictable rainfall and more frequent extreme weather events can wipe out an entire season's harvest, including the seed stock a farming family had set aside for the following year, permanently ending that family's line of a particular variety if no backup exists elsewhere.

### **Modern Seed Storage Methods**

Advances in modern science have significantly improved the effectiveness of seed storage. The following methods are now widely used around the world.

### Cold Storage

Storing seeds at a temperature ranging from 0°C to 10°C considerably reduces their metabolic rate. Using this method, seeds can be preserved for 5 to 10 years without their germination capacity being affected. This method is widely used in national seed banks. Cold storage works on a simple biological principle: seeds are living tissue, and like all living tissue their cells carry out metabolic processes that gradually consume stored energy reserves and accumulate cellular damage over time. Lowering the temperature slows these metabolic processes dramatically, in much the same way refrigeration slows spoilage in food. Most national seed banks maintain multiple tiers of cold storage: medium-term facilities kept around 4°C for seed that will be regularly accessed for research or distribution, and long-term "base collection" facilities kept well below freezing for seed intended to remain untouched for decades.

### Vacuum Storage

In vacuum storage, seeds are preserved in an environment from which oxygen has been removed or significantly reduced. Because aerobic insects and fungi cannot survive in the absence of oxygen, this method has the capacity to preserve seeds for 10 to 20 years. Removing oxygen halts the activity of the aerobic insects, mites, and fungal spores that are the primary agents of stored-seed spoilage, since these organisms require oxygen to survive and reproduce. Vacuum sealing also slows the seed's own oxidative metabolic processes, further extending shelf life. In practice, vacuum storage is often combined with desiccants and opaque, moisture-proof packaging (such as multi-layer foil pouches) so that oxygen, moisture, and light—the three main enemies of seed viability—are all controlled simultaneously.

### Moisture Control

Maintaining seed moisture content between 5 and 8 percent is considered the optimal condition for storage. Excessive moisture leads to fungal growth, while excessively low moisture can damage seed cells. Technological moisture-control systems are now in widespread use. Moisture content is widely regarded by seed scientists as the single most important variable governing storage life; there is a well-established rule of thumb that for many species, every 1 percent reduction in seed moisture content roughly doubles storage life, within a safe range. Because of this outsized effect, modern seed banks invest heavily in precise drying and moisture-monitoring equipment, often using silica-gel-based desiccation chambers or mechanical dehumidifiers rather than relying on ambient drying alone, in order to bring seed lots down to and hold them at their optimal moisture level before long-term storage begins.

### Airtight Storage

Storing seeds in high-quality metal or plastic airtight containers, along with moisture-absorbing materials such as silica gel, is a very low-cost and practical method in wide use. Both individual farmers and community seed banks can adopt this method. This approach is often described as the most accessible entry point into modern seed-preservation practice, since it requires no electricity, refrigeration, or specialized infrastructure—only an airtight container and a desiccant. Reusable colour-indicating silica gel, which changes colour as it absorbs moisture and can be dried out in an oven and reused, makes this method particularly practical for smallholder farmers and community seed-saving groups operating with limited budgets.

### Comparative Overview of Seed Storage Methods

The table below compares traditional and modern seed-storage methods based on their effectiveness.

| Storage Method   | Temperature /Condition | Storage Duration |
|------------------|------------------------|------------------|
| Clay pot         | Room temperature       | 1–2 years        |
| Cold storage     | 10°C                   | 5–10 years       |
| Vacuum storage   | Without oxygen         | 10–20 years      |
| Cryopreservation | –196°C                 | Centuries        |



## Seed Banks

A seed bank is an institution that systematically collects, classifies, and preserves seeds over the long term. These function as living libraries that hand down biological diversity to the next generation.

### National Seed Banks

In India, the National Bureau of Plant Genetic Resources, located in New Delhi, holds more than 400,000 seed samples, ensuring seed security at the national level. These banks store and preserve seeds at temperatures of  $-18^{\circ}\text{C}$  or lower. National seed banks typically operate under formal international frameworks, such as agreements coordinated through the International Treaty on Plant Genetic Resources for Food and Agriculture, which govern how genetic material is collected, stored, and shared between countries and research institutions. Beyond simple storage, these institutions also carry out regular seed-viability testing, regeneration (periodically growing out a sample of stored seed to produce fresh seed stock before germination rates decline too far), and detailed cataloguing of each accession's origin, characteristics, and genetic data.

### Community and Village Seed Banks

Community seed banks, which operate at the grassroots level, provide farmers with direct access to seed. In addition to preserving traditional knowledge, they facilitate seed exchange and the revival of local varieties. Many voluntary organizations in Tamil Nadu are at the forefront of this effort. Unlike large centralized national gene banks, community seed banks are designed for active use rather than passive long-term storage; farmers deposit and withdraw seed each season, effectively keeping traditional varieties "alive" in cultivation rather than frozen in a vault. This living-collection model has an important genetic advantage, since seed that continues to be grown out each year continues to adapt to changing local conditions, whereas seed held in static cold storage does not evolve further. Community seed banks also frequently serve as hubs for training, seed fairs, and knowledge exchange between farmers, strengthening the social networks that traditional seed-saving depends on.

## Biotechnology and Seed Preservation

Advances in biotechnology have brought about revolutionary changes in seed preservation. These techniques prove most effective when combined with traditional methods.

### Cryopreservation

Cryopreservation, which stores seeds in liquid nitrogen ( $-196^{\circ}\text{C}$ ), has the capacity to preserve seeds for centuries without their genetic integrity being affected. In a study conducted in 2020, some seeds preserved through cryopreservation for more than 50 years were found to retain a germination capacity of over 85 percent (Indian Council of Agricultural Research, 2020). At such extremely low temperatures, essentially all biochemical and metabolic activity within the seed comes to a halt, meaning that the biological "clock" that normally drives seed aging is effectively stopped rather than merely slowed. This makes cryopreservation particularly valuable for species whose seeds do not tolerate conventional drying and cold storage well (so-called "recalcitrant" seeds), for which specialized cryopreservation protocols involving controlled dehydration and rapid freezing have been developed. Because the process requires liquid nitrogen infrastructure and careful technical handling, it remains largely confined to major national and international gene banks rather than village-level seed-saving efforts.

## Practical Guidance for Farmers

- Effective seed storage is a practical skill that can be applied not only by scientists but by every farmer. The following steps should be followed carefully.
- First select seeds from healthy plants that produced a good yield.
- Dry the seeds thoroughly in the shade (without direct sunlight) for 2–3 days.
- Collect the seeds in airtight containers together with silica gel.
- Label each container with the seed variety, and the date and place of collection.
- Store in a cool, dark, moisture-free location.

- Carry out germination testing every year.
- Keep multiple duplicate copies in different locations.

### Challenges and Solutions

Seed-preservation efforts face a range of challenges. It is essential to identify these challenges and design systematic solutions.

| Challenges                                        | Solutions                                                 |
|---------------------------------------------------|-----------------------------------------------------------|
| Low awareness among farmers                       | Village-level awareness camps                             |
| Lack of access to modern technological facilities | Government-subsidized distribution of storage equipment   |
| Seed damage caused by climate change              | Cold storage and cryopreservation                         |
| Lack of interest among the younger generation     | School- and college-level agricultural education programs |

Traditional seeds are not mere agricultural commodities; they stand as the collective genetic memory of human civilization. The loss of this priceless biological asset would constitute an irreversible catastrophe. When modern seed-storage technologies from cold storage to cryopreservation operate in conjunction with traditional methods, seed preservation becomes far more effective. The integration of government policy support, community participation, and scientific knowledge will carry this effort to success.