AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 01 (January, 2026)
Available online at http://www.agrimagazine.in

Seed Bank Treasure Hunts: Rescuing Climate-Resilient Genes from the Brink of Extinction

Vijaya Lakshmi, *Pramod Kumar Meghwal and Prathamesh Raipure
Ph.D. Scholar, Dept. of Genetics and Plant Breeding, ICAR- Indian Institute of Agricultural Biotechnology - 834010, Ranchi, Jharkhand, India
*Corresponding Author's email: pramodkumarmeghwal1998@gmail.com

In the quiet cold of underground vaults and mountain laboratories around the world, millions of seeds rest in perfect darkness. They are small, unassuming and easily overlooked yet they represent the biological memory of agriculture, a living archive of everything humans once grew and everything we may need to grow again. These seeds come from ancient grains cultivated by early farmers, hardy wild relatives overlooked by modern agriculture and crop varieties that once thrived in landscapes now transformed by climate change. Together, they form a treasure trove of genetic diversity waiting to be rediscovered.

Seed banks were created as insurance against crop loss, but today they have become something more urgent: a global rescue mission. As climate change accelerates, threatening food production in ways scientists are only beginning to understand, researchers are racing to find genes capable of withstanding heat, drought, pests, salt and new pathogens. Many of these genes have disappeared from modern high-yield varieties, lost during decades of breeding that favoured uniformity over resilience. The only place they still exist is in seed banks, often preserved from ecosystems that no longer resemble their past. In this new era of uncertainty, scientists have begun what some call treasure hunts inside these vaults journeys into agricultural history to find the traits that could safeguard the future of food.

Why Modern Crops Lost the Resilience They Once Had

Today's commercial crops are remarkably productive, capable of delivering high yields under controlled conditions with the help of fertilizers, irrigation and pesticides. But their strengths come at a cost. Over generations of breeding for yield, taste, and uniform appearance, many crops lost the genetic diversity that once helped them survive in wild or variable environments. While traditional varieties from centuries past might tolerate harsh weather, poor soils or emerging pests, modern cultivars often lack these defenses. When breeders selected for uniformity, they unintentionally removed alleles that contributed to stress tolerance. Drought resistance, for example, is usually the result of many small genes working together and selecting high-yield lines sometimes eliminates these subtle traits. The same is true for heat tolerance, disease resistance and salt adaptation. This narrowing of genetic diversity leaves agriculture vulnerable. As weather patterns change, pests migrate into new regions, and extreme conditions become more common, crops face pressures they were never bred to endure. The solution lies not in synthetic chemicals or expanding farmland, but in rediscovering the genetic building blocks preserved in seed banks.

Seed Banks: Silent Guardians of Lost Diversity

Seed banks are among the most extraordinary scientific institutions on Earth. From the Svalbard Global Seed Vault tucked deep into the Arctic permafrost, to national repositories in Mexico, Ethiopia, India, and Japan, these facilities store millions of samples collected from farms, forests, villages and wild landscapes. Some seeds date back decades; others represent landraces maintained by communities for centuries.

These banks act as a "genetic time capsule," preserving everything modern agriculture has forgotten. Wild wheat that thrives in scorching deserts. Rice that grows in deep floodwaters. Millet that survives prolonged drought. Beans resistant to fungal diseases. These seeds might never appear in supermarkets, but their genes contain powerful adaptations that modern crops desperately need. Collecting them is not simple. Many wild relatives grow in remote, politically unstable or rapidly disappearing habitats. Seed collectors often travel to rugged mountains, dry savannas, and monsoon wetlands to secure samples before they vanish. In a sense, they are racing both ecological destruction and time itself. Inside the vaults, seeds are dried, catalogued and stored at sub-zero temperatures. They may sleep for decades, but their genetic secrets remain intact, waiting for breeders to unlock them. A conceptual world map shown in Figure 1, major international seed banks preserving global crop diversity.

Figure 1: Global Seed Bank Network

The Treasure Hunts Begin: Searching for Climate-Resilient Traits

When researchers open a seed bank database, they are not simply choosing plants; they are searching for clues. Each sample represents a place and time where a crop evolved alongside its environment. Wheat from the Fertile Crescent may carry genes for drought adaptation. Maize from the Mexican highlands might tolerate cold nights. Rice growing in monsoon regions likely learned to endure floods.Scientists use genomic sequencing to scan thousands of seeds at once, looking for variations associated with resilience. When a promising gene is identified, seeds are germinated, grown, and tested under controlled stress: high heat, saltwater, limited irrigation or exposure to pathogens. The plants that survive reveal their secrets.These traits can then be reintroduced into modern varieties through crossbreeding or gene editing. Breeding programs once focused on yield; today focus on both productivity and adaptability, embracing diversity rather than eliminating it. Some genes require subtle changes. Others turn out to be breakthroughs. One of the most famous examples is "submergence tolerance" in rice. Farmers in flood-prone regions of South and Southeast Asia often saw their fields destroyed after extended monsoon floods. A single gene, SUB1A, discovered in a traditional Indian rice variety stored in a seed bank, allowed rice plants to survive two weeks underwater. Introducing this gene into modern varieties has already protected millions of hectares of farmland. Seed banks are full of similar hidden treasures waiting to be uncovered.

Rescuing Genes from Vanishing Wild Relatives

Wild crop relatives are disappearing faster than scientists can collect them. Climate change, land conversion, and habitat fragmentation threaten many of the ecosystems where these plants evolved. Without intervention, entire lineages and the genetic adaptations they contain could be lost forever. Seed collectors often describe their work as a race. In some cases, they return to a collection site years later and find it drastically changed: urban construction, drought-killed vegetation, or invasive species overtaking native flora. The urgency is real. Losing wild relatives means losing the raw material needed to adapt agriculture to a hotter, more unpredictable world. These rescue missions are sometimes dramatic, botanists rappelling into cliffs to collect rare wild beans, navigating deserts to find heat-tolerant barley, or trekking through dense forests to reach isolated populations of wild bananas nearly extinct in the wild. Every sample collected expands the genetic toolkit available to future breeders. Botanists are collecting seeds from wild crop relatives in remote environments threatened by climate change, as shown in Figure 2.

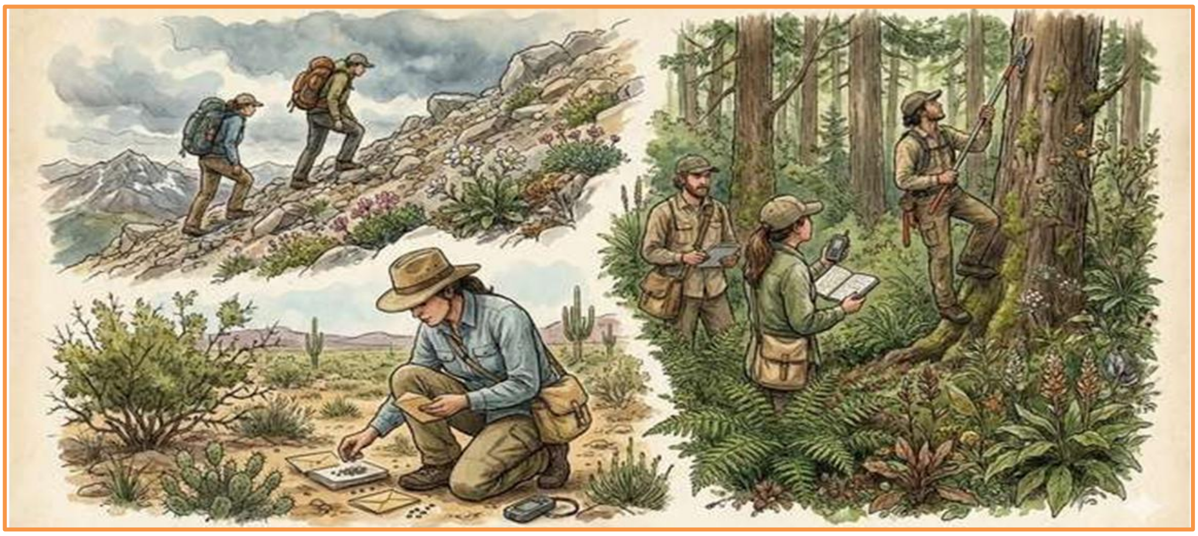

Figure 2. Collecting Wild Crop Relatives

How Genetics Brings Old Diversity into Modern Fields

Once a valuable trait is discovered, it must be brought into varieties that farmers can actually grow. For most of history, this meant traditional crossbreeding: planting wild relatives next to domesticated crops, making crosses and selecting for desired traits generation after generation. This process is slow and often introduces unwanted traits alongside the beneficial ones. Modern genetics changes this process dramatically. Genomic selection allows breeders to predict performance based on genetic markers, speeding up selection cycles. CRISPR enables precise editing, inserting beneficial alleles directly into elite crop lines without dragging along undesirable traits. Advanced phenotyping tools measure root growth, photosynthesis, and stress responses with extraordinary accuracy. These technologies allow breeders to use wild genes in ways that were impossible even a decade ago.For example:

1. **Heat-tolerant wheat** from Middle Eastern wild varieties
2. **Salt-resistant barley** from coastal relatives
3. **Drought-hardy maize** derived from highland landraces
4. **Fungal-resistant beans** from African wild populations

As climate pressures intensify, these innovations make the difference between crop failure and survival.

The Role of Indigenous Knowledge and Traditional Farming

Seed banks store the physical seeds, but many traditional traits also survive through memory knowledge passed down through generations of farmers. In regions where landraces are still grown, Indigenous communities have preserved traits long before genomics discovered them. Their knowledge about drought-tolerant sorghum, flood-resistant rice or nutrient-dense millet often aligns with modern scientific discoveries. Collaborative programs now bring together Indigenous farmers, breeders, and researchers to combine traditional wisdom with genetic screening. In this sense, the Second Green Revolution is as much social as scientific. Seed banks hold the seeds; communities hold the stories. Both are needed to build climate-resilient crops. A conceptual visualisation, shown in Figure 3, of traditional farmers and scientists working together to preserve and use crop genetic diversity.

Figure 3: Indigenous Knowledge Meets Modern Genetics

The Race Against Climate Change

Climate change is not waiting for agriculture to catch up. Heatwaves, droughts, saltwater intrusion, shifting disease ranges, and erratic rainfall already threaten harvests in many regions. Some crops are approaching the limits of their physiological tolerance.The seeds stored in global banks represent evolutionary strategies that took thousands of years to develop. They offer immediate pathways to adaptation pathways far faster than waiting for new mutations or hoping for technological fixes. The urgency is clear: If agriculture does not adapt, entire regions may become unable to grow staples like rice, wheat or maize. Seed banks are the genetic libraries that can help rewrite those outcomes.

Yet these treasures are only useful if scientists continue to explore them and if funding and global collaboration remain strong. A seed left in a vault is not a solution; it is a possibility. Its power lies in being rediscovered, understood and reintroduced into the world. A conceptual infographic showing in Figure 4, drought, heat, flood and salinity impacts on global crop regions.

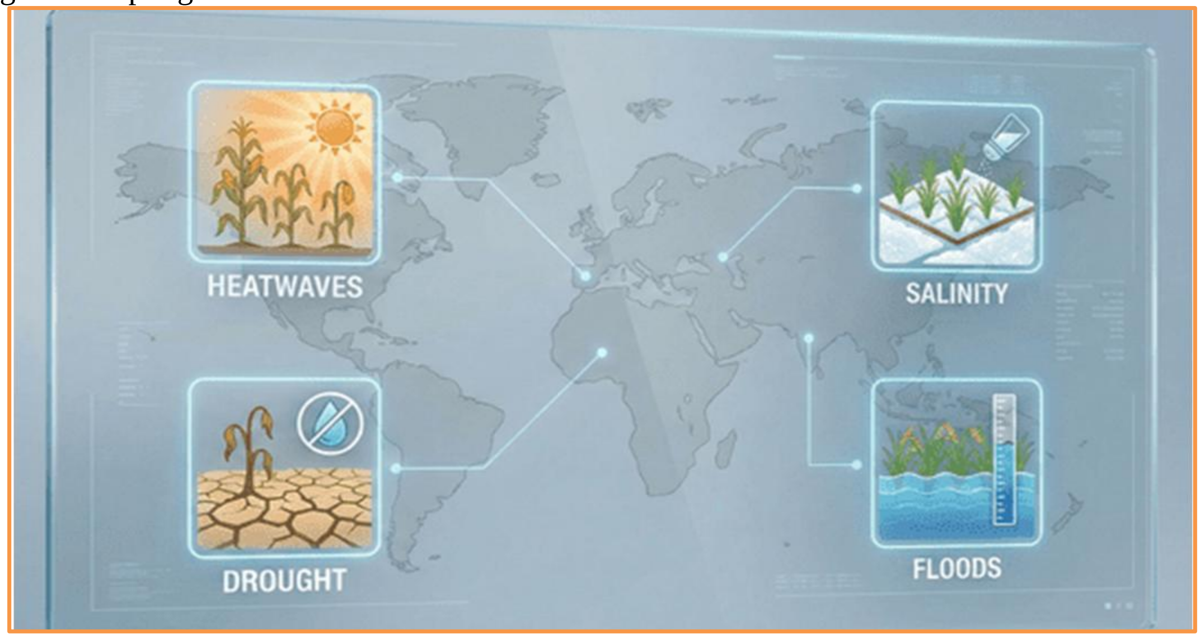

Figure 4. Climate Threats to Global Agriculture

Conclusion: Seeds of the Past, Solutions for the Future

In the end, the story of seed banks is a story of hope. Within vaults protected from fire, flood, and time itself lie the tools for safeguarding agriculture in a warming world. Each seed carries not just genetic information but a fragment of human history a crop grown by people whose conditions, environments, and challenges shaped its evolution. Today, scientists embark on treasure hunts through these collections not out of nostalgia, but out of necessity. The genes that helped crops survive ancient droughts or extreme climates may be the same genes needed to protect global food supplies today. The future of farming will depend not only on new technologies but also on ancient diversity. The seeds preserved for decades in frozen vaults may determine which crops can withstand the storms of the 21st century. They are reminders that resilience is often found in the past and that the key to feeding future generations lies in the genetic heritage we choose to protect, study and bring back to life. The treasures hidden in seed banks are not just relics. They are blueprints for the next chapter of agriculture.

References

1. Dempewolf, H., Eastwood, R. J., Guarino, L., Khoury, C. K., Müller, J. V., & Toll, J. (2014). Adapting agriculture to climate change: a global initiative to collect, conserve, and use crop wild relatives. *Agroecology and Sustainable Food Systems*, *38*(4), 369-377.
2. Khoury, C. K., Brush, S., Costich, D. E., Curry, H. A., De Haan, S., Engels, J. M., ... & Thormann, I. (2022). Crop genetic erosion: understanding and responding to loss of crop diversity. *New Phytologist*, *233*(1), 84-118.
3. Sun, Y., Guo, L., Zhu, Q. H., & Fan, L. (2022). When domestication bottleneck meets weed. *Molecular Plant*, *15*(9), 1405-1408.