

## Climate-Resilient Seed Varieties: A Pathway to Sustainable Agriculture

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The agricultural scene on earth is changing due to climate change, characterized by unpredictable rainfall, extended droughts, temperature increase, and influx of pests. Small and Marginal farmers particularly face these threatening challenges as they are the foundation of food security in most developing countries. The introduction and use of climate-resilient seed varieties are perhaps one of the most promising solutions that can arise from agricultural science and farmer-led innovation initiatives. Intended to withstand drought, flood, heat, and pests, such seeds are an important adaptation measure towards the resilience of farming systems. This article examines the history and potential of climate-resilient seeds, their role in helping secure food security, empowering farmers, and mitigating the impacts of biodiversity loss and technological advancements.

### Introduction

Seeds are millennia-old emblems of life, toughness and survival. However, in contemporary times, they are under more stress than ever due to a rapidly shifting climate. One of the most at risk of climate variability is agriculture, which generates approximately one-third of the world's greenhouse gas emissions (FAO, 2021). Experts in Agriculture in Asia, Africa, and Latin America have reported drops in yield because of dry spells, unexpected floods, and outbreaks of new pests. It has been estimated that one out of 10 percent of wheat yields is likely to decline because of warmer temperatures in India alone (Lobell et al., 2012). There are no words to convey the importance of quality seeds as the foundation of agricultural productivity and resilience, as noted by Patel and Behera (2025). Their study argues that seed quality forms the bedrock of agricultural productivity, and resilient seeds are fast becoming the basis of climate-smart farming.

### What Are Climate-Resilient Seed Varieties?

Resilient seeds are those that are capable of withstanding the environmental challenges/challenges brought about by climatic conditions like drought, floods, heat waves, salinity, and pests. In comparison to traditional types of such seeds, plant breeding, biotechnology, and traditional knowledge systems have been used to develop climate-resilient seed varieties of species. An example is how shocks at the International Rice Research Institute (IRRI) merged traditional flood-tolerant landraces with high-yielding modern varieties to develop swarna-sub1, a rice capable of 14 days fully submerged (Mackill et al., 2012). In this case, the contribution of complementary technologies such as drones is worth mentioning. Drones allow tracking the state of crops in real time and can assist farmers in making the most appropriate decisions regarding what type of seed and what kinds of inputs to use in their fields (Pradhan et al., 2025).

## Historical Evolution: From Traditional Knowledge to Biotechnology

Seeds have been evolving in the climate all the time. Originally, native agricultural societies selected varieties that were suitable for the local environment. Indicatively, results of centuries of research have seen Ethiopian farmers producing drought-tolerant sorghum. Nevertheless, following the 1960s, the Green Revolution led to a shift in interest to high-yielding varieties, which are less resilient to environmental stress. Even as yields rose, these seeds had high irrigation water requirements, as well as fertilizer and pesticide needs, methods that proved unsustainable in a warming world. At the turn of the 21<sup>st</sup> century, resilience breeding came back into favour. With the recent introduction of genomics, marker-assisted selection, and CRISPR-controlled gene editing into agriculture, it is now possible to create more specific and more rapid stress-tolerant seed (Varshney et al., 2021). The process of combining old landraces with modern breeding technologies has produced a new generation of seeds adapted to climate change.

## Case Studies

### 1. Drought-Tolerant Maize in Africa

At least 60 varieties of Drought-Tolerant Maize for Africa (DTMA) have been distributed in 13 countries. It is revealed that these varieties yield 20-30% more during droughts than conventional maize (CIMMYT, 2015). African farmers now trust these seeds to protect harvests because they are used by millions of farmers.

### 2. Scuba Rice in South Asia

Areas in Bangladesh and India that are prone to floods have seen changes in farming with the introduction of varieties of scuba rice, including Swarna-sub1 and IR64-sub1. Such rice species can survive up to two weeks in flooding environments and therefore provide food security during monsoon floods.

### 3. Heat-Resistant Wheat in India

In northern India, increases in temperature during the grain-filling phase of wheat significantly lower yields. Research centers have come up with heat-tolerant varieties of wheat, such as HD 2967 and HI 8759, which have the ability to endure heat stress at the end of the season. Now they are extensively embraced by farmers in Punjab and Uttar Pradesh.

### 4. Salt-Tolerant Rice in Coastal Areas

As seawater levels rise, the intrusion of salinity is devastating coastal agricultural lands. It is due to the CSR of rice varieties, which were designed by the Central Soil Salinity Research Institute (India), that allow farmers in coastal Odisha and West Bengal to continue producing rice.

## Socio-Economic Impact of Climate-Resilient Seeds

Resilient seeds directly solve the issue of food insecurity by making sure harvests are even when the weather is unpredictable. FAO estimates that crop losses globally could be reduced by a factor of 2025 with the adoption of stress-tolerant seeds. In the case of India, climate-resistant seeds give farmers analogous benefits when faced with climate stress.

## Challenges and Concerns

On the one hand, climate-sensitive seeds promise tremendous potential, but raise issues of the sovereignty of seeds, prevailing costs, and availability. Low awareness, poor distribution channels, and distrust of formal seed systems usually hinder adoption. More so, the uptake of technology in Indian agriculture has a tendency to prioritize the low cost of products at the expense of low trust, implying that the ecosystem of building up to the success of climate-resilient seeds will have the same need.

## The Road Ahead: Building Resilient Seed Systems

The emergence of climatically robust seeds will not stop being a mere start. To reach their potential, several steps are essential for them:

**1. Enhancement of Seed Systems-** Enhancement of the last-mile delivery by using cooperatives of farmers, government subsidies, and online seed system platforms.

- 2. Participatory Breeding-** Engaging the farmers in breeding programs to make sure that varieties are adapted to the requirements of localities.
- 3. Policy Support** - The governments need to give subsidies, crop insurance, and advertising to encourage adherence.
- 4. Public-Private Partnerships** - Investigation institutes, seed companies, and groups of farmers can work together to foster more rapid innovation and access.
- 5. Conservation Agro-Biodiversity** - To preserve genetic trait variety, we should promote community seed banks and the use of traditional seed banks.

## Conclusion

The emergence of climate-resistant seed varieties can be likened to hope during uncertainty. They are not only the values of endurance but also the values of creativity and survival. The seed is not only a grain of life anymore; it is the best line of self-protection against hunger in human beings because of the growing magnitude of climate change. Nevertheless, the most significant obstacles are the awareness of farmers and the trust in technology. The promise of the seeds is achievable only when farmers comprehend, access, and embrace such seeds with the help of additional technologies, such as drones.

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