

Drought-resistant crops: The science behind survival in heatwaves

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Introduction

In recent years, heatwaves and prolonged dry spells have become frequent guests across agricultural lands, knocking on the door with scorching winds and leaving behind parched soils and shattered hopes. For farmers in India and around the globe, climate change is no longer a distant concern; it's an everyday reality. But amidst this challenge, science offers a ray of hope: drought-resistant crops - plants that have evolved or been engineered to survive, even thrive, with little water. As global temperatures rise and rainfall patterns shift, developing and adopting drought-resilient crop varieties is not just a scientific pursuit—it's a survival strategy for humanity. But what makes a crop drought-resistant? How do scientists build crops that can beat the heat? And what does the future of farming look like in a hotter, drier world? Let's dig deep into the science behind this agricultural revolution.

Why Drought-Resistance Matters More Than Ever

According to the IPCC (Intergovernmental Panel on Climate Change), India is among the countries most vulnerable to climate-induced droughts. In 2023 alone, vast tracts of Maharashtra, Rajasthan, and southern states faced severe water shortages, crippling the kharif season. Traditional crops wilt under such harsh conditions, leading to yield losses, food insecurity, and farmer distress. In such a scenario, drought-resistant crops are no longer a luxury—they're a necessity. These crops:

- ✓ Use water efficiently
- ✓ Withstand heat stress
- ✓ Maintain yield under water-limited conditions

From pearl millet to chickpea, and from maize to sorghum, researchers are developing resilient varieties that can withstand nature's wrath.

The Science of Surviving Drought

So, what makes a crop resistant to drought? It's not just one trait—it's a complex interplay of physiological, biochemical, and molecular mechanisms. Let's explore some of the key strategies:

Deep and Efficient Root Systems

Plants like sorghum and pigeon pea develop deep root systems that tap into underground moisture when the

topsoil dries up. Some improved wheat varieties also show vertical root angles, allowing them to mine water from deeper layers. Researchers at ICRISAT have developed chickpea varieties with deeper roots and enhanced root hair development, improving their water uptake.

Stomatal Regulation

Stomata are tiny pores on leaves that control gas exchange and water loss. Drought-resistant crops close their stomata during peak heat to reduce transpiration. Some also show early morning stomatal opening, taking in CO₂ when it's cooler and less risky. Example: Pearl millet varieties with low stomatal density conserve water better and stay greener for longer during dry spells.

Osmotic Adjustment

Under drought, some plants accumulate solutes like proline, glycine betaine, and sugars to retain cellular water—a process known as osmotic adjustment. These compounds act as internal “antifreeze” agents, stabilizing proteins and membranes. Example: Drought-tolerant rice varieties often show higher proline content, keeping their leaves turgid under stress.

Drought-Induced Hormones

Plant hormones like abscisic acid (ABA) play a pivotal role in signalling drought stress. ABA promotes stomatal closure and activates stress-responsive genes that help the plant survive. New biotechnological approaches are exploring ways to enhance ABA sensitivity in crops, improving their stress response.

Stay-Green Trait

Some crops maintain green leaf area longer under drought—a trait known as “stay-green.” This prolongs photosynthesis and ensures better grain filling. Example: Sorghum stay-green lines have shown superior performance in rainfed regions of central India.

Early Maturity

Escaping drought is as effective as resisting it. Short-duration crop varieties complete their life cycle before the dry spell hits hard. Case Study: ICRISAT-developed chickpea variety ‘JAKI 9218’ matures in just 85–90 days, ideal for post-rainy season sowing in water-scarce areas.

Molecular and Genetic Approaches

Modern drought tolerance research is going beyond the field and into the genome.

Marker-Assisted Breeding (MAB)

This method uses DNA markers linked to drought-tolerant traits to speed up breeding programs. Example: In rice, the gene DREB1A (Dehydration Responsive Element Binding protein) is used to track and select stress-tolerant lines.

Genetically Modified (GM) Crops

Although still controversial in India, GM technology has created transgenic maize and soybean with enhanced drought tolerance abroad. The “DroughtGard” maize developed in the US uses a bacterial gene (cold shock protein B) to maintain cellular stability under water stress.

Genome Editing (CRISPR/Cas9)

Genome editing offers precise changes without introducing foreign DNA. Scientists have used CRISPR to:

- ✓ Knock out water-loss genes
- ✓ Enhance root architecture
- ✓ Fine-tune hormonal signalling

This holds great promise for future non-GMO drought-resilient crops.

Indigenous Crops Leading the Way

Sometimes, the answers lie not in laboratories but in traditional crops that farmers have used for centuries:

- ✓ Finger millet (Ragi): Exceptionally drought-hardy, grown in Karnataka and Odisha.
- ✓ Kodo millet and barnyard millet: Thrive on marginal soils with minimal water.
- ✓ Moth bean and cowpea: Heat-tolerant legumes perfect for arid zones.

Promoting these crops, along with modern breeding, can diversify and strengthen food systems.

Success Stories from Indian Science

India's public research system has made remarkable progress in developing drought-tolerant varieties:

Drought-Tolerant Rice (DRR Dhan Series)

Developed by ICAR-IIRR, DRR Dhan 42 and DRR Dhan 44 perform well under both irrigated and drought-prone areas, securing food for millions.

Chickpea Varieties from ICRISAT

‘JG 14’, ‘JG 11’, and ‘JAKI 9218’—these kabuli and desi chickpeas are known for early flowering, deep roots, and high yield in semi-arid regions.

Drought-Hardy Maize by CIMMYT and ICAR

New maize hybrids like ‘HM-4’ and ‘Shaktiman-4’ perform well in Bihar and UP even under water stress, ensuring food and fodder security.

Farmers at the Frontline

Scientific innovation is vital—but equally important is farmer participation. Initiatives like:

- ✓ Participatory Varietal Selection (PVS)
- ✓ On-farm trials
- ✓ Farmer Field Schools

have ensured that the best-performing varieties reach the people who need them most.

Technology and Tools for Drought Management

New tools are aiding farmers in choosing the right crops and practices:

- ✓ Mobile apps like mKisan give weather updates and seed recommendations.
- ✓ Remote sensing and drones monitor crop health and moisture stress.
- ✓ Precision irrigation (like drip systems) ensures water is used efficiently.

The Road Ahead: Challenges and Hopes

While the progress is promising, several challenges remain:

- Many drought-tolerant varieties lack market appeal or consumer preference.
- Extension systems are understaffed and underfunded.
- Climate unpredictability is increasing faster than breeding cycles.

But hope persists. With policy support, farmer education, and public-private partnerships, drought-resilient farming can become mainstream.

Conclusion: Seeds of Survival

In a world inching towards water scarcity, drought-resistant crops are not just tools of adaptation—they are seeds of survival. They embody the union of traditional wisdom, modern science, and farmer resilience. As the sun scorches the fields, these crops stand strong—not just to grow food, but to grow hope.

And in every resilient seed sown, we find a silent but powerful reply to climate change:

“We will not just survive—we will thrive.”

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