

# Heat-Resilient Crops: How Plants Survive Extreme Temperatures

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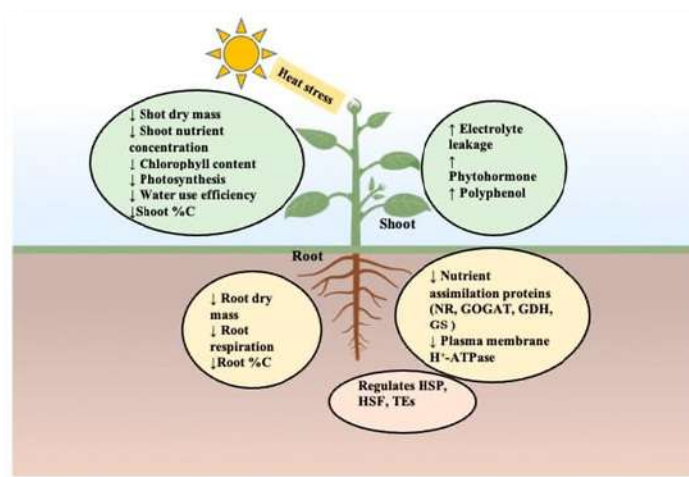
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In recent years, farmers across India have observed a worrying trend—summers are becoming hotter, longer, and more difficult to manage. Heatwaves now arrive earlier, persist longer, and strike with greater intensity. In states such as Telangana, Andhra Pradesh, Maharashtra, and Rajasthan, daytime temperatures frequently cross 40–45°C, pushing crops far beyond their comfort limits. Even a slight rise in temperature can disturb a plant's internal processes, and prolonged heat spells can destroy pollen, reduce flowering, damage leaves, and cut yields by 20–60%. Yet, amid this harsh environment, some crops stand firm. Their leaves stay greener, their flowers last longer, and grain formation continues even when surrounding fields struggle. These crops are heat-

resilient, equipped with extraordinary internal mechanisms that allow them not just to survive but to perform under extreme temperatures. Their story is one



of science, evolution, and adaptation—knowledge every farmer and agriculture student should understand.

## Heat Stress: A Silent Threat to Indian Agriculture

Heat stress often operates

silently. Unlike pests or diseases, heat does not leave visible symptoms immediately, yet the internal damage begins quickly. High temperatures accelerate water loss, interrupt nutrient flow, destabilize cell membranes, and hinder photosynthesis—the plant's most vital food-producing process.

Heat stress is especially dangerous when it strikes at sensitive stages like flowering. Crops such as rice,

wheat, maize, red gram, and groundnut suffer irreversible yield losses when exposed to high temperatures during reproductive phases. Pollination fails, grains remain empty, and leaves lose vigour.

Another rising concern is night-time warming. Warm nights prevent plants from resting or recovering. Increased respiration results in higher carbohydrate loss and reduced energy reserves. All of this leads to significant drops in productivity—even if daytime temperatures are manageable.

This highlights why understanding and developing heat-resilient crops is essential for India's climate-smart agriculture.

### **How Heat-Resilient Crops Keep Their Cool**

Plants may appear still and silent, but internally they are constantly adjusting, repairing, and adapting. Heat-resilient crops depend on a range of finely tuned survival mechanisms, some inherited from ancestors and others shaped through natural selection. Key mechanisms include:

#### **1. Cooling Through Evaporative Loss — Transpiration**

Plants cool themselves primarily through transpiration, the evaporation of water from leaf surfaces. When temperatures rise, this evaporation carries heat away.

Heat-resilient plants excel in precise stomatal control, enabling them to:

- Open stomata just enough to stay cool
  - Minimize excessive moisture loss
  - Coordinate stomatal activity with sunlight intensity
- This fine balance often keeps their leaf temperatures several degrees lower than the surrounding air.

### **2. Deep and Efficient Root Systems**

Heat and drought often occur together. While surface soil dries quickly, deeper layers retain moisture. Heat-tolerant crops use this advantage by developing:

- Deep taproots
- More lateral roots
- Thicker root tissues
- Greater root length density

These root traits help crops like millets, sorghum, pigeon pea, and cotton access deeper water reserves and essential nutrients, ensuring continued growth during heatwaves.

### **3. Heat-Shock Proteins (HSPs)**

Heat-shock proteins act as the plant's emergency repair system. High temperatures can cause essential proteins to lose their shape, leading to failure of critical processes. HSPs stabilize, refold, and protect these proteins, allowing plants to maintain photosynthesis, respiration, and growth under stress.

### **4. Antioxidants: Internal Firefighters**

Heat stress increases the production of Reactive Oxygen Species (ROS)—harmful molecules that damage cells. Heat-resilient crops produce antioxidants to neutralize ROS, including:

- Ascorbic acid (Vitamin C)
- Glutathione
- Carotenoids
- Enzymatic antioxidants such as catalase and peroxidase

These molecules prevent internal tissue damage and delay aging.

### **5. Thicker, Waxy Leaves**

Some crops develop structural adaptations like:

- Thicker leaves for water storage
- Waxy leaf coatings that reduce water loss
- Reflective surfaces that reduce heat absorption

Crops such as sorghum, pearl millet, and sesame use leaf wax as a protective “natural sunscreen.”

## 6. Stable Cell Membranes

At high temperatures, cell membranes become leaky, causing ions and nutrients to escape. Heat-resilient varieties have membranes rich in stable lipids that maintain flexibility under stress, helping to:

- Prevent ion leakage
- Maintain nutrient transport
- Preserve metabolic functions

This invisible adaptation often determines survival during heatwaves.

## Naturally Heat-Tolerant Crops

Some crops evolved in dry, harsh environments and naturally possess strong heat-resilience traits:

- **Sorghum** — strong roots and waxy leaves
- **Pearl millet** — thrives even at 45–48°C
- **Foxtail & Barnyard Millets** — rapid recovery after stress
- **Pigeon Pea** — deep roots and strong antioxidant systems
- **Black Gram & Cowpea** — withstand extreme summer heat
- **Cotton** — heat-friendly canopy and physiology

Such crops are gaining renewed interest as climate stress intensifies.

## Can Sensitive Crops Be Made Heat-Resilient?

Yes. Plant breeders are identifying heat-tolerance genes from hardy crops and transferring them into rice, wheat, maize, and pulses. Important physiological markers used in selecting heat-tolerant varieties include:

- Cooler canopy temperatures
- High membrane stability
- Greater pollen viability
- Strong antioxidant activity
- Robust root traits

Modern tools like genomic selection, marker-assisted breeding, and CRISPR gene editing are accelerating the development of heat-resilient varieties.

Alongside improved genetics, farming practices such as mulching, micro-irrigation, crop diversification, and adjusting sowing windows also boost heat tolerance.

## Looking Ahead: The Future Belongs to Heat-Resilient Crops

By 2050, India will require far more food to support its growing population. Yet rising temperatures threaten to reduce yields of major crops. Heat-resilient crops offer a powerful solution. They form the backbone of climate-smart agriculture, ensuring food security even under unpredictable weather.

These crops are not merely survivors—they are the future drivers of global agriculture, capable of feeding millions in a warming world. Understanding their physiology is essential for building a resilient and sustainable farming system capable of meeting future challenges.

## References

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