

# ***Agronomic Measures for Mitigating High Temperature Stress in Food Crops: Strategies for Climate-Resilient Production***

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## **ABSTRACT**

Rising global temperatures due to climate change pose a serious threat to food crop productivity by disrupting the physiological, biochemical and developmental processes. High temperature stress adversely affects germination, photosynthesis, reproductive development and ultimately yield. This review synthesizes key agronomic strategies which include adjustment of sowing date, crop and cultivar selection, soil and water management, use of mulches, nutrient management and cropping system diversification. Recent advancements such as conservation agriculture, precision farming practices and adoption of the Integrated Approach for mitigating high temperature stress in food crops are also taken into consideration.

## **INTRODUCTION**

**C**limate change is raising global temperatures, increasing the intensity and frequency of heat waves that is

reducing crop production. A single heat wave can reduce agricultural output by 50% and extreme heat is considered as a frontline threat

to food security. The global crop yields could decline by 3-12% by mid-century and 11-25% by century's end under a high-emission scenario (Ortiz-Bobea *et al.* 2021). By the mid century many breadbasket regions will experience routine day time maxima in the 40-45 degree Celsius range at critical crop stages. Heat stress is defined as where temperatures are hot enough for sufficient time that they cause irreversible damage to the crop plant. According to Food and Agriculture Organization, climate change could reduce global crop yields by upto 10-25% by 2050 in the absence of the adaptation measures, while the Intergovernmental Panel on Climate Change projects that 32-132 million people may be pushed into extreme poverty due to climate-related impacts (Portner *et al.* 2022), highlighting the urgency of the mitigating strategies.

### **Impact of high temperature stress on Agriculture**

High temperature stress affects crops at multiple levels. Temperature basically affects the rate of metabolism involved in the growth and development of the crop. In general, developmental processes (germination, ontogenic changes, leaf initiation and meiotic division) are more thermal sensitive than growth and photosynthesis and also have more sharply defined optima although there are substantial differences in sensitivity amongst processes.

- **Physiological Impact:** Reduced photosynthesis, increased respiration and impaired enzyme activity.
- **Reproductive Impact:** Pollen sterility, poor fertilization and reduced grain set.
- **Biochemical Impact:** Generation of Reactive oxygen species causing oxidative damage.

- **Yield Impact:** Reduced grain weight, quality deterioration and yield instability.

High-temperature stress poses a critical threat to global food security by inducing pollen sterility, reducing photosynthetic efficiency, and accelerating grain maturation, which collectively results in significant yield losses in staples like wheat and rice. To reduce these impacts agronomic mitigation strategies focus on "heat escape" through adjusted sowing dates, physical temperature regulation by incorporating mulching, canopy cooling and chemical priming using foliar protectants. By integrating these Heat-Smart practices ranging from conservation agriculture to precision irrigation farmers can easily grow crops against thermal extremes, stabilizing production and protecting livelihoods in increasingly high temperature conditions. The greatest danger of heat injury occurs when soil is exposed to insolation, reaching temperature as high as 55 degree Celsius to 75 degree Celsius (Lundegardh, 1949). Global warming has emerged as a critical challenge to agricultural sustainability, with temperature projected to rise by 1.5-2 degree celsius by the mid 21<sup>st</sup> century.

### **Global and Indian Scenario of High Temperature stress in food crops**

Global and regional food systems are defined by the "perfect storm" of rising thermal extremes, where every 1 degree celsius increase in mean temperature triggers a 3% to 7% decline in staple crop yields. While the global scenario focuses on stabilizing international trade and supply chains against heat-induced volatility in the Americas and Europe, the Indian context focuses on urgent national food security as terminal heat stress threatens the Indo-Gangetic "breadbasket." To mitigate these risks, a unified agronomic shift is necessary when transitioning from traditional farming to "Heat-Smart" agriculture through the strategic adjustment of sowing

dates to the adoption of conservation tillage to preserve soil moisture and the widespread application of foliar protectants.

### Management of High Temperature stress

- **Adjusted sowing dates and crop scheduling:** The primary goal of this is "heat escape". By analyzing long-term weather data, sowing dates can be manipulated so that the sensitive reproductive phase (anthesis and grain filling) occurs during cooler ambient temperatures. Timely sowing can help in escaping the heat stress resulting in optimum yield.
- **Irrigation and water management:** Water acts as a thermal buffer. Micro-irrigation (drip and sprinkler) maintains high soil moisture, facilitating uninterrupted transpiration. Canopy cooling includes applying light irrigation during peak sunshine hours and can reduce the micro-environment temperature by 2°C to 5°C, preventing the denaturation of photosynthetic enzymes.
- **Mulching and soil temperature regulation:** Organic mulches (crop residues like rice straw) and plastic mulches create a physical barrier between solar radiation and the soil surface. This reduces soil evaporation and keeps the root zone significantly cooler.
- **Nutrient Management:** Balanced fertilization, specifically increasing Potassium (K) and Silicon (Si), strengthens the plant's cell walls and improves osmotic adjustment. Nutrient basically helps in crop growth and development. Each essential nutrient plays an important role in the different physiological process and mechanism.
- **Foliar Application and Plant Growth Regulators:** Foliar application of nutrients

and Plant Growth Regulators (PGRs) serves as a rapid-response strategy to "prime" crop physiology against sudden thermal spikes. This enhances osmotic adjustment and structural integrity, while osmoprotectants protect cellular proteins from heat-induced denaturation. PGRs act as vital signaling molecules that affect the plant's internal antioxidant defense systems and neutralize harmful Reactive Oxygen Species (ROS) and maintain stomatal regulation.

- **Selection of Heat tolerant varieties:** Adopting cultivars specifically bred for "Stay-green" traits or high antioxidant capacity is the foundation of heat resilience. Short-duration varieties are also preferred to complete the life cycle before the onset of extreme summer. The use of heat tolerant varieties and appropriate crop selection based on local climatic conditions further enhances the resilience.
- **Conservation Tillage:** Zero or minimum tillage leaves crop residues on the surface, which improves soil organic carbon and moisture retention. This creates a resilient "buffer" against sudden temperature spikes compared to conventionally tilled, bare soil which results in minimum loss due to high temperature.
- **Precision agriculture :** Precision agriculture (PA) transforms heat stress management from a reactive, field-wide struggle into a proactive, data-driven strategy. By utilizing real-time sensors and satellite imagery, farmers can identify specific "thermal hotspots" within a field and deploy interventions exactly where the crop is most vulnerable.

### CONCLUSION

High-temperature stress is no longer a peripheral threat but a central challenge to

agricultural sustainability in the 21st century. As highlighted in this review, while genetic improvements are vital, agronomic interventions provide the most immediate and scalable defense. The integration of "heat-escape" sowing schedules, precision water management, and the strategic use of foliar protectants can significantly optimize the yields. For a truly climate-resilient production system, an Integrated Agronomic Approach combining conservation tillage with site-specific nutrient management is necessary. Adoption of these practices will be the deciding factor in securing the livelihoods of farmers and the food security in the environment.

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