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Heat Stress Responses in Plants: Unraveling the Thermal Sensory Machinery and Protective Strategies

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Abstract: *Repeated super high temperature events increasingly threaten global crop production and natural ecosystems. Spatial clustering of extreme heat in the dry season leads to chronic heat stress that disrupts iron metabolic pathways and fundamental plant physiological processes, from photosynthetic carbon assimilation to cellular membrane stability; such stress takes a toll on yield. Here, we propose a detailed review on the mechanisms of plant responses to high temperature stresses, including thermal sensing perception and associated acclimation response. Conceptually, thermal stress is characterized by changes in plasma membrane fluidity, leading to transient Ca^{2+} fluxes and the generation of reactive oxygen species (ROS). The events associated with those signaling platforms activate several cascade signal transduction networks, mainly consisting of mitogen-activated protein kinases (MAPKs) and calcium-dependent protein kinases (CDPKs), finally resulting in activation of heat shock factors (HSFs). Thus, plants activate the expression of molecular chaperones, specifically heat shock proteins (HSPs), in order to avoid protein denaturation and allow for correct folding. Simultaneously, a potent antioxidant system composed of both enzymatic (e.g., superoxide dismutase) and non-enzymatic metabolites is activated to counteract an overwhelming oxidative injury. Moreover, metabolic reprogramming establishes a reserve of compatible solutes that upholds osmolarity and membrane stability. Especially, for Indian agriculture, where staple crops like Triticum aestivum are under higher threat to terminal heat stress, this knowledge of the genetic and biochemical pathways becomes very important. This analysis underscores the vital need of molecular breeding strategies in conjunction with advanced biotechnological interventions to create thermotolerant cultivars raising a challenge towards global food security against the incessant advance of climate change*

Keywords: Thermotolerance, Heat Shock Proteins, Oxidative Stress, Signal Transduction, Photosynthesis