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Terminal Heat Stress in Plants

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Global food security is being haunted by the rapid increase in population and drastic changes in the climate . In the wake of changing climate, drought, and heat stress have become the most important limiting factors to crop productivity and ultimately the food security. The reduced precipitation and changed rainfall patterns are causing the frequent onset of droughts around the world . Severe droughts cause substantial decline in crop yields through negative impacts on plant growth, physiology, and reproduction (Barnabas *et al*., 2008). Abiotic stresses are often interrelated, either individually or in combination, they cause morphological, physiological, biochemi- cal, and molecular changes that adversely affect plant growth and productivity, and ultimately yield.Heat, drought, cold, and salinity are the major abiotic stresses that induce severe cellular damage in plant species, including crop plants. Fluctuations in temperature occur naturally during plant growth and reproduction.

Morphological changes in terminal heat stresses: Temperature can modify developmental and growth rates in plants. Correspondingly, heat stress affects agronomic traits at every developmental stage, but the pre-flowering and anthesis stages are relatively more sensitive to high temperature compared to post-flowering stages . Specifically, short periods of high temperature at the pre-flowering and flowering stages can reduce grain number per spike and yield. This can be attributed to lower ability of pollen to germinate, and to the rate of pollen tube growth . For example, wheat plants exposed to 30 °C during a 3-day period around anthesis had abnormal anthers, both structurally and functionally,in 80% of florets **(**Cossani *et al*., 2012).

Physiological Responses to terminal heat stress: Heat stress causes multifarious, and often adverse, alterations in plant growth, development, physiological processes, and yield .One of the major consequences of high temperature stress is the excess generation of reactive oxygen species (ROS), which leads to oxidative stress.

Molecular changes in responses to Heat stress: Stimuli of abiotic stress perceived by the plant generate an integrate signalling cascade that is generally triggered by receptors embedded in plasma membrane of the cell . Secondary messengers such as Ca2+ ion and calmodulins , calcium-dependent protein kinases (CDPKs), calcineurin B-like (CBL) and CBL-interacting protein kinases (CIPKs) act as calcium sensor. This event switches the mitogen-activated protein (MAP) kinases on, followed by the activation of transcription factors and subsequently the concerned heat-shock protein (HSP) genes (Suri and Dhindsa 2008).

Terminal Heat stress management approaches: In general, the tolerance of the plant to heat stress is characterized by minimal damage to photosynthetic machinery and increased biosynthesis of the protective compounds . Photosynthesis and reproductive phase of plant growth are highly sensitive to high temperature stress. So, a heat tolerant variety in this regard should have a better photosynthetic rate, membrane thermo stability and fruit setting under high temperature (Nagarajan *et al*., 2010). Some other indirect parameters used for selection include, the grain filling duration and grain weight . Developed heat tolerance index to evaluate the recovery potential after heat shock as an important tolerance indicator. Although it is an easy criteria, its effectiveness for wide range of crops is yet questionable.

Conclusions and Future Prospect

Plants have evolved sophisticated adaptive mechanisms to withstand diverse and complex abiotic stresses. With the advent of new technologies such as genomics and genetic transformation, significant progress has been made in understanding these complex traits in higher plants. However, the commercial application of positive research outputs requires further validation of products or prototypes in the field. These efforts will lead totangible practical outcomes that may help mitigate the effects of climate change, especially with respect to drought and heat stresses, and will contribute to improved crop productivity and food security, particularly in areas such as India.

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