Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 04, Issue: 05 (SEP-OCT, 2024)
Available online at http://www.agriarticles.com

High Temperature Stress

(N. Soundharya and *K.V. Eniyavan)
J.K.K. Munirajah College of Agricultural Science, T. N. Palayam, Gobi, Erode-638506
*Corresponding Author's email: eniyavankv2@gmail.com

Plant stress refers to any adverse conditions that negatively affect a plants growth, development or functioning. These stresses can be broadly categorizedinto two types;

1. Abiotic stress: caused by non-living factors
2. Biotic stress: caused by living organisms.

In response to stress-related protein, adjusting hormone levels, altering gene expression, and modifying their growth patterns. Prolonged or serves stress can however, lead to growth inhibition, reduced yield and, in extreme cases, plant death. High temperature stress in plants occurs when temperatures exceed the optimum range for plant growth affecting physiological processes and leading to impaired development. When higher plants are exposed to temperature exceeding their optimal growth conditions by more than 5®C, they exhibit a specific range of cellular and metabolic responses essential for survival in such environment. Plants have evolved a variety of physiological, cellular and molecular mechanisms to cope with elevated temperatures. This stress disrupts photosynthesis, respiration water relations, and enzyme activities, resulting in reduced yields, stunted growth and in severe cases, plant death. High temperature stress can also induce oxidative damage, impair reproductive development and trigger the expression of heat shock proteins as defence mechanisms. Understanding and mitigation the effects of heat stress is critical in agriculture, especially with the increasing challenges posed by climate change.

Clasification

According to Thermotoleranc Larcher (1995), he classified all the plant species into three different groups under high temperature stress:

i) Heat-sensitive species: Some these species injured at 39 to 40 °C and they are mostly eukaryotic algae and lichens in hydrated state. Some, soft-leaved terrestrial plants are also falls in this classification.

ii) Relatively heat-resistant species: In this type, plants can survive a 30 minutes exposure to 50 to 60 °C and up to 70 °C it may tolerate shorter exposure to temperature. They are mainly found in dry and sunny region.

Heat-tolerant species: These are thermophilic prokaryotes that can tolerate temperature of 75 to 90°C up to 105 °C Some Archaebacteria can also survive even higher temperatures, after an acclimation treatment.

1. Impact of High Temperature Stress on Physiological, Growth and Yield Processes

High temperature stress is known to impact development and plant growth and various physiological and yield processes. Some critical responses are discussed below

1.1. Physiological processes: The degradation of chlorophyll molecules may be associated with production of reactive oxygen species under high temperature stress. High temperature stress lower leaf chlorophyll content. The dropping of chlorophyll during high temperature stress resulted in change in the chlorophyll a:b ratio due to premature leaf senescence. High temperature stress increases thylakoid membrane. Photosystem (PS) II is considered to be highly temperature sensitive and its activity lower at high temperatures due to the changes in the properties of thylakoid membranes where PS II is located. The PS I system is usually more conserved under high temperature stress than the PS II. Net photosynthesis and stomatal conductance are inhibited by high temperature stress owing to decreased Rubisco activase enzyme.High temperature stress can influence photosynthesis either through regulation by decreasing flow of CO2 into mesophyll tissue and stomatal closure.

1.2. Growth processes and Development: High temperatures generally higher the leaf appearance rates. Cell growth and cell division are the two main processes take place in plant growth. High temperature stress can stimulate cell elongation rates and cell division .High temperature stress transform the initiation and period of developmental phases.under high temperature stress Panicle initiation in sorghum was delayed by 28 days. It can also cause the cessation of panicle development at any stages in between flowering and panicle initiation. In cereal crops, longer duration of vegetative and reproductive development are often necessary to develop reproductive and leaves and tillers to give assimilate supply during grain fillGrain or seed fill periodis the time from seed-set to physiological maturity. In most crop species, particularly those with a physical restriction for growth of seeds, such as cereals – rice, legumes - groundnut or soybean, yield is mainly purpose of seed numbers per unit area and seed fill period .

1.3. Reproductive processes and yield components: Reproductive processes, particularly those of megasporogensis and microsporogensis, anthesis, pollination, pollen tube growth, fertilization and early embryo improvement are all greater susceptible to high temperature stress.Some of the Failure in this processes increases early embryo abortion, leading to a lower number of grains and limiting yield or decreases fertilization.Exposure to high temperature stress in the time of flowering results in pollen sterility and loss of seed-set in legumes - groundnut, soybean and cereals - wheat, rice. Temperature of greater than 37ºC for a interval as short as 1 hour during the flowering stage decreases seed-set in cereals (rice) similarly, exposure to temperature of >33ºC for the first half of the day decreases pollen viability and thus seed-set in legumes (groundnut).

2. Stages Sensitive to High Temperature Stress

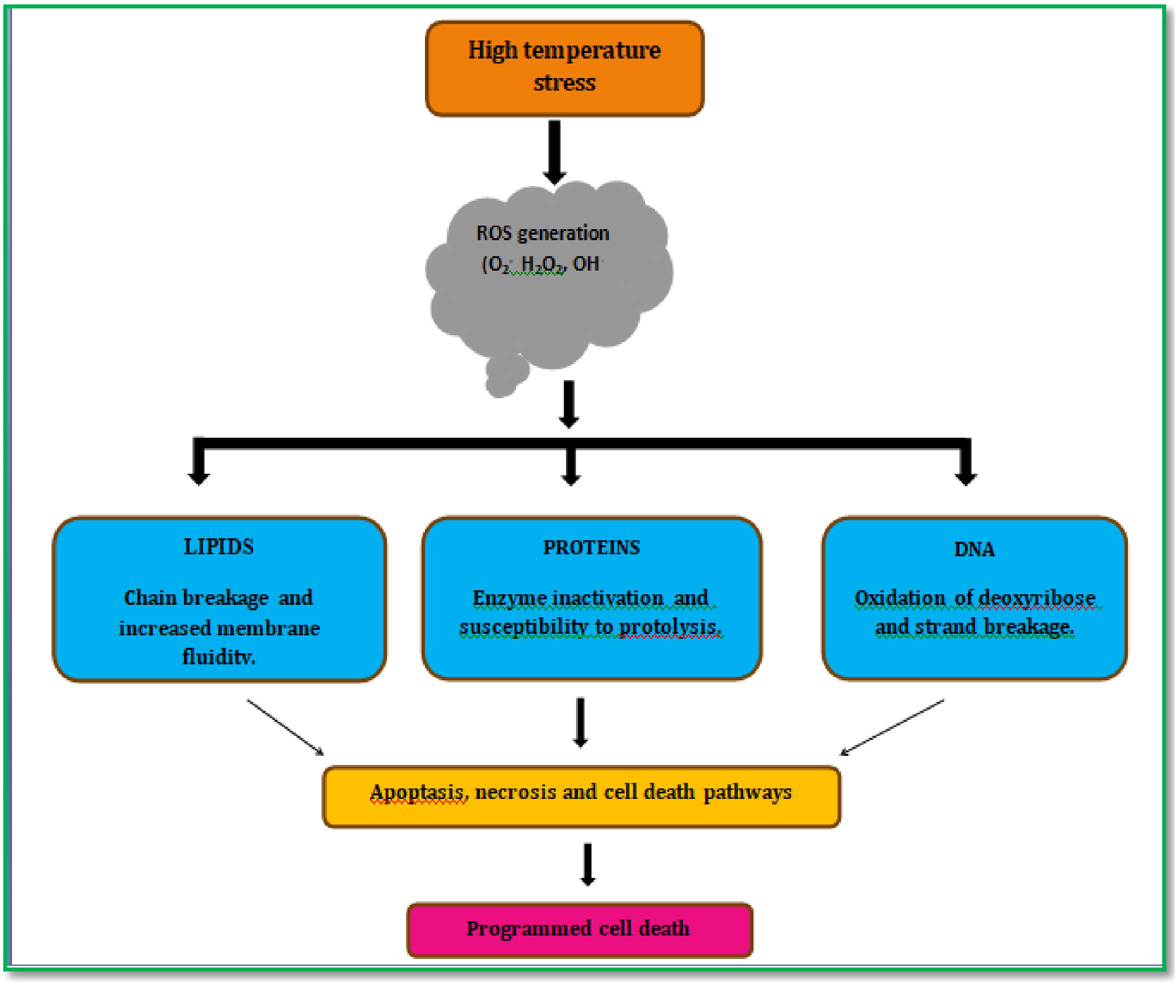
High temperature stress tolerance tends to be the decreases progressively during flowering and early seed filling stages and high during early vegetative stages. High temperature stress is most sensitive stages of development to generally in cereals - flowering and during panicle development and in legumes - during flowering and the period just prior to flowering. The stages sensitive to high temperature stress in some selected crop species mentioned:

1. Rice - Early microspore following meiosis and flowering.
2. Wheat - Floret formation and anthesis.
3. Maize - Tasselling and seed set.
4. Sorghum - Panicle initiation and anthesis.
5. Soybean - Flowering and pod set.
6. Groundnut - 3 days before anthesis and 15 days after anthesis.

3. High Night-time Temperatures

High night-time temperature had a more pronounced negative impact than daytime temperatures on the yield. High night time temperature reduced crop yields, reduced grain yield and quality, confused circadian clocks, increased risk of heat damage, and altered ability of leaves to sustain carbon supply to grains. The persistence of high night-time temperatures (HNT) over long periods during the crop cycle can potentially impact a wide range of growth and development stages. The major processes drastically affected by night-time warming such as photosynthesis, respiration, etc. ultimately cause yield and economic losses.

4. Plant adaptation to High temperature stress



4.1. Heat shock protein (HSP) genes: Heat shock protein is a kind of proteins that are found in plants, play a role in many processes, plant development and stress response. In plants, HSPs act as chaperones to help plants tolerate biotic and abiotic stress. HSPs are usually located in the cytoplasm under normal conditions, but they quickly move to the nucleus when the plant is under stress. HSP transcripts increase significantly when plants experience high temperature.

1. **HSP90:** In this type plants cell has highly expressed proteins, where its content is 1-2% of total protein level in cytoplasm. The basic eukaryotic molecule HSP90 assist the proper maturation of other protein substrates and proper folding, various among them are main activators of biological circuits.
2. **HSP70s:** It is the most widely studied member found in all plants and animals. It is called as on basis of molecular weight 70k Da and act as molecular chaperons. It function as basic chaperon that it assists in folding of regulatory proteins prevent aggregation of denatured proteins.
3. **Small heat shock proteins (SHSPs):**The sHSPs having molecular weight ranging from 12 to 42k Dalton are unique and evolutionally. HSP20 named so as MW are in the range of 15-22k da. It binds to the foregin protein substrates in a co-operative manner but their function does not depend on ATP

4. **HSP100:** Heat shock protein 100 is a protein that helps organism tolerate stress, such as high temperatures. HSP100 is only abundant during sustained heat stress, not under common chemical stresses. HSP100 associates into trimeric complexes and is mostly found in the cytoplasm.
5. **HSP60:**Heat shock protein 60(HSP60) is a protein that plays role in a variety of cellular process, including;
   1. Cell signalling – HSP60 is involved in cells signalling.
   2. Mitochondrial DNA – HSP60 helps transmit and replicant mitochondrial DNA.
   3. Protein folding – HSP60 helps proteins fold, unfold, and transport within cells.

HSP60 are induced by physical and chemical stressors like heat, hypoxia, infections and heavy metals. It is found in both prokaryotic and eukaryotic cells, and in mammals it's mainly found in the mitochondria.

Conclusion

Understanding the mechanisms that lead to improved reproductive success at high temperatures is critical to the development of high temperature tolerant crops. It approaches to improving existing genotypes and developing new ones that can better tolerate abiotic stresses, such as high-temperature conditions. HTS in plants lead to severe physiological biochemical and molecular disruptions that impair growth, development and productivity. However, plants have evolved several adaptive responses, such as heat-shock proteins, antioxidant systems, and hormonal signalling to mitigate the effect of high temperatures. Sustainable agriculture practices, including timely irrigation and shading also help manage heat stress, contributing to better crop resilience and productivity in the face of rising global temperatures.

References

1. Maduraimuthu Djanaguiraman and P.V. Vara Prasad (2014) High Temperature Stress, *Plant Genetic Resources and Climate Change, Chapter 12, 202-212.*
2. Khan, S., Jabeen, R., Deeba, F., Waheed, U., Khanum, P., & Iqbal, N. (2021). Heat Shock Proteins: Classification, Functions and Expressions in Plants during Environmental Stresses, *Journal of Bioresource Management*, 8 (2).
3. Ye J, Zhong T, Yu D and Sun S – (2021) Physiological and Molecular Biology of High Temperature Stress in Plants, *Annals of Agricultural & Crop Sciences*, Volume 6 Issue 2.