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# THERMO-TOLERANCE MECHANISM IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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## Abstract

Wheat is grown in tropical and subtropical regions of the world that experience different biotic stresses. India's wheat production is affected by heat stress on about 13.5 million ha Uttar Pradesh (UP) produce over 30% of India's wheat production and about 14% of its rice production. Several agronomic traits are affected by heat stress conditions. Physiological and biochemical traits are controlled by multiple genes that affect heat tolerance. The CTD is dependent on many factors, including air temperature, humidity, soil conditions, and incident radiation. Using RWC, plants can be evaluated for their water status relative to their fully turgid state. In these conditions, however, plants often adapt osmotically, which maintains turgor pressure and makes the definition of 'full turgidity' difficult to determine. In wheat, chlorophyll content is related to heat tolerance and stay-green traits. The chlorophyll estimation will determine the relative amount of chlorophyll in the plant and absorbance will be measured at 663nm and 645nm, as well as other traits.

## 1. Introduction

Wheat (*Triticum aestivum* L.) is India's second-most significant food crop, after rice (Gupta *et al.*, 2008). A winter crop is wheat, and India ranks second in production worldwide. Heat & cold stress have a negative impact on crop germination, growth, and development. Terminal heat stress severely affects Wheat yield (Pandey *et al.*, 2013). For 85% and 82% of the world's population, wheat provides basic calories and protein, respectively (Sharma *et al.*, 2019 & Chaves *et al.*, 2013). Generally, heat tolerance refers to a plant's capacity to survive and make a profit in an environment with a variety of biotic challenges. (Rahaie *et al.*,). Wheat is grown in tropical and subtropical regions of the world that experience different biotic stresses. In this regard, even related species and even various tissues and organs within the same species may differ greatly from one another. Different mechanisms have been developed by plants to survive at higher temperatures (Rodriguez *et al.*, 2005 & Wang *et al.*, 2004). India's wheat production is affected by heat stress on about 13.5 million ha (Joshi *et al.*, 2007) Uttar Pradesh (UP) produce over 30% of India's wheat production and about 14% of its rice production. UP and Rajasthan have both had relatively large climate impact on wheat since 1980, with 0.87°C and 0.52°C, respectively, being the two states with the largest increases in growing season temperature since 1980, respectively (Jennifer & Ramanathan *et al.*, 2014).

Heat tolerance genes in wheat are one of the major focus areas for developing future heat tolerance strategies. The new crop varieties will have to be adapted to the future climate by improving heat tolerance and responding to prominent temperature (Halford *et al*., 2009). A wheat's terminal heat tolerance is useful in screening it. The purpose of these screening techniques is to simulate the effects of heat stress in the target environment.

Physiological changes induced by heat stress which cause leaf senescence in winter season (Dhyani *et al*. 2013, Almeselmani *et al*., 2011). Under heat stress, plants respond in a variety of morphological, physiological, biochemical, and molecular ways. Wheat is morphologically adapted to heat stress in a number of ways, including enhancing germination capacity, vegetative development, leaf rolling and folding, and delaying early leaf senescence. Under heat stress, early maturation may also be an avoidance mechanism (Adams *et al*., 2001). The synthesis of stress-related proteins can also be triggered by molecular changes such as altered gene expression and transcript accumulation (Iba *et al*., 2002). Physiological and biochemical traits are controlled by multiple genes that affect heat tolerance. Promising methods for examining the genetic basis of thermo tolerance involve the use of molecular markers (Maestri *et al*., 2002). The marker-assisted selection (MAS) technique can be applied to traits that contribute to heat tolerance, such as Chl (Li *et al*.), in order to select these traits more efficiently. Physiological selection traits such as canopy temperature (CT) are ideal in many ways since they can be measured quickly, easily, and inexpensively (Cossani & Reynolds *et al*., 2012). A quantitative trait locus (QTL) has been identified in a mapping population where yield and stay green traits are correlated (Kumar *et al*. 2010; Vijayalakshmi *et al*., 2010). It has been reported that membrane thermo tolerance in wheat can result from both additive and dominant gene action (Dhanda & Munjal *et al*., 2012) as well as QTL with SSR markers (Ciuca & Petcu *et al*., 2009). Heat-tolerant cultivars have not been significantly affected by MAS (Tuberosa & Salvi *et al*., 2006; Ortiz *et al*., 2008). Wheat genomic regions that are associated with variability in physiological traits require much more information. An investigation was made into the genotypes of Indian wheat's chlorophyll content, heat tolerance, and correlation to molecular markers.

## 2. Mechanism of heat tolerance

The physiological reactions of thermal and susceptible genotypes during different plant development stages, especially grain filling, can provide insight into heat tolerance mechanisms. Early maturity under high temperature is linked to lower yield losses in different plants, which indicates early maturity is a mechanism of escape (Adams *et al*., 2001). In different growth stages, plants experience a variety of environmental stresses and their mechanism of responding may vary based on the type of stress (Queitsch *et al*., 2000).

When temperatures reach a certain level for a limited amount of time, they can be reduced to yield. Temperatures should be in the normal range of 18-22°C for higher yields. In order for plants to mature at an early stage, high temperature must change their anatomy (Porter *et al*., 2005). The high temp. causes cellular damage that may result in cell death. Injuries due to heat lead to protein denaturation. If the temperature is low, enzymes are inactive and protein synthesis is reduced (Howarth *et al*., 2005). There are a variety of ways in which plants can be affected by high temperatures, low temp. and high soil temp. Additionally, many crops are very sensitive to high temperatures. The ability to tolerate high temp. is one of the ways a plant maintains self-integrity to avoid high temperature and create a good metabolic pathway as a result (Anand *et al*., 2020).

## 3. Morphological mechanisms

### *3.1 Grain filling duration (GFD)*

Maintaining high grain yield is one of the most important factors for improving wheat under heat stress (Aziz et al., 2018). According to Dwivedi et al. (2017), the wheat reproductive phase is highly sensitive to heat stress, and in regions with the largest wheat production, the grain filling period experiences the highest temperatures that have an impact on the process of grain filling (Pradhan and Prasad et al., 2015; Singh et al., 2011). Heat stress has been proven to have a significant negative impact on the quantity, weight and quality of wheat kernels (Mohammadi et al., 2012; Hutsch et al., 2019). Due to heat stress during anthesis and grain filling, grain yield drastically decreases (Semenov and Stratonovitch et al., 2015). Wheat's maturity period and grain filling time are both reduced by heat stress by up to 15%. (Ahamed et al., 2010).

## 4. Physiological Mechanism:

### *4.1. Canopy temperature (CTD)*

CTD describes the difference in canopy temp. from ambient temp. (Deva *et al*., 2020). When wheat is exposed to heat stress, CTD is critical in maintaining the physiological basis for grain yield. The cool canopy is a significant principle for wheat's ability to tolerate heat during grain filling. The CTD is dependent on many factors, including air temperature, humidity, soil conditions, and incident radiation. Drought and heat stress are strongly associated with lower canopy temperature (CT), and CT appears to have some common genetics basis under both conditions (Pinto *et al*., 2010). Wheat genotypes with a greater CTD have been found to have increased photosynthetic enzyme activity and greater leaf conductance (Sarkar *et al*., 2021).

### *4.2. Relative Water Content (RWC)*

Using RWC, plants can be evaluated for their water status relative to their fully turgid state. In these conditions, however, plants often adapt osmotically, which maintains turgor pressure and makes the definition of 'full turgidity' difficult to determine (John *et al*., 2008).

### *4.3. Chlorophyll Content*

In wheat, chlorophyll content is related to heat tolerance and stay-green traits (Cao *et al*., 2015; Feng *et al*., 2014). During heat stress, wheat biomass and yield are both affected by chl (Tattaris *et al*., 2016). A high chl concentration in wheat can be a criterion for selecting heat-resistant wheat (Munjal & Dhanda 2016; Ramya *et al*., 2014). A high chl concentration under thermal stress has a low photo inhibition (Choudhary *et al*., 2020; Talebi*et al*., 2011). A chl content that is associated with transpiration efficiency can contribute to heat tolerance (Raynolds & Trethowan*et al*., 2007). The chlorophyll estimation will determine the relative amount of chlorophyll in the plant and absorbance will be measured at 663nm and 645nm (Kamble*et al*., 2015).

## 5. Biochemical mechanism

### *5.1. Starch synthesis*

Wheat grain contains a significant amount of starch, which accounts for 55% to 75% of its dry weight (Gillies *et al*., 2012). The wheat grain produces two types of starch granules during the GFD (Zheng *et al*., 2014). As a result of amylopectin readily decreasing under high temperatures, starch is more heat sensitive than protein (Farooq *et al*., 2011), thereby reducing starch content. During heat stress, wheat grain starch content reduces at a critical level, resulting in a reduction in kernel weight and diameter (Poudel & Poudel *et al*. 2020). Soluble starch synthase (SSS) is the enzyme responsible for starch synthesis.It is extremely heat-sensitive. Wheat under heat stress loses SSS activity, which inhibits grain maturation and starch storage (Prakash *et al*., 2004).

### *5.2. Antioxidant response*

Studies have shown that under heat stress, damage to membranes increases and antioxidant levels decrease in wheat during seedling, anthesis (Narayanan et al., 2015) & grain filling. (Suzuki *et al*., 2014). Thermal stress causes plants to accumulate antioxidants from different pathways (Bokszczanin & Fragkostefanakis *et al*., 2013). Wheat's antioxidant defense systems are classified as enzymatic or non-enzymatic (Sattar et al., 2020). In addition to converting superoxide into H2O2, SOD is one of the most important antioxidants. In contrast, GPX, APX and CAT regulate ROS detoxification (Buttar et al., 2020).

Superoxide dismutase, catalase, and ascorbate peroxidase activities are extenuated at 50°C, but they are initially enhanced at this temperature (Chakrabortty & Pradhan *et al*., 2011). The highest antioxidant activity was shown at 35-40°C in tolerant wheat varieties, and at 30°C in susceptible varieties (Chakrabortty & Pradhan *et al*., 2011). In wheat, catalase and superoxide dismutase activities are capable of achieving thermo tolerance (Almeselmani*et al*., 2009) and demonstrate a strong relation with thermal stress during the reproductive stage (Zhao *et al*., 2007).

## 6. Molecular mechanism:

### *6.1. Protein synthesis*

During heat stress, plants develop some defense mechanisms, such as expressing specific genes that are only expressed under stress conditions (Feder *et al*., 2006). Stress-Induced Proteins (SIPs) are heat-shock proteins. When wheat leaves are exposed to heat stress, they synthesize heat-shock proteins. A membrane association must be considered when explaining the role of HSPs in adapting to heat stress since two thirds of chloroplast HSPs are transferred to thylakoids under heat stress (Bernfur *et al*., 2017). In wheat, heat stress leads to unfolding of proteins in the ER and cytosol via ROS regulation mechanisms (Kataoka *et al*., 2017; Sun and Guo, 2016).

### *6.2. Omics approaches*

Among the major components of omics are genomics, transcriptomics, metabolomics & proteomics. In wheat plants, several genes containing genomic DNA are involved in heat stress tolerance (Deshmukh *et al*., 2014). The role of genes in wheat heat tolerance has been determined by genomic screening and genome expression studies (Yeh *et al*., 2012). A transcriptome is produced by mRNA of heat tolerance genes; a proteome is produced by translating the mRNAs into functional proteins. A small non-protein coding RNA plays a role in post-transcriptional gene expression in plants. Wheat heat tolerance mechanisms can be better understood by studying microRNAs and micromics (Chinnusamy *et al*., 2007). A metabolicomics approach can be used to phenotype genetically modified plants as well as to test for similarity, determine gene functions, and observe responses to biotic and abiotic stresses (Abdelrahman *et al*., 2020). Plant metabolites can be altered under heat stress based on metabolomics studies (Roessner and Bowne, 2009).

## Conclusion:

Wheat is suffering from heat stress more frequently due to high temperatures across the globe. Ultimately, grain yield is reduced because of heat stress' substantial effects on grain filling duration and rate. A grain yield's impact on heat stress depends on its timing, duration and intensity. One of the main issues with wheat production worldwide is heat stress. In order to create wheat varieties that are both thermo tolerant and high yielding, it is important to thoroughly comprehend the various metabolic and developmental processes that plants use to cope with heat stress. This review paper quickly explains the morpho-physiological, biochemical, and molecular bases of heat tolerance as well as numerous elements of heat stress. It is commonly recognized that molecular analysis could support increasing economic crop output, but wheat under heat stress must have its full potential yield expression estimated at the field level. It is necessary to combine several agronomic alternatives with biochemical and molecular methods in order to examine the true impact of heat stress at the field level.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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