IMPACT & MANAGEMENT OF HEAT STRESS IN WHEAT

(A REVIEW)

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ABSTRACT

Around the world, heat stress is a major obstacle to wheat production; a number of biotic and abiotic factors have a negative impact on wheat productivity. The negative effects of increased temperatures and the detrimental impact of climatic changes on plant growth & development have resulted in an unprecedented decrease in wheat production. An increase in warmth is predicted to cause a 6% decline in wheat output. A complete understanding of wheat's morpho-physiological responses to heat stress may be helpful in developing appropriate strategies for enhancing wheat yield under heat stress. Furthermore, looking into potential management strategies may increase the wheat growth's sustainability and productivity. The primary conclusions of the review are as follows: The following are some of the ways that heat stress affects wheat: (1) A substantial reduction in plant water use efficiency, seed germination, seedling growth, and cell turgidity; (2)Decreased grain yield: Heat stress at crucial wheat growth phases, like flowering and grain filling, can result in poor grain set, reduced grain size, and lower overall yield; (3) the growth of oxidative damage to the chloroplasts, the senescence of leaves, the reduction of photosynthesis, and the inactivation of the enzymes responsible for photosynthetic processes; (4) HS also affects the length, growth rate, assimilate translocation, and grain settling, this so affects the grain number and size; (5) Some techniques for controlling heat stress in wheat include breeding, discovering quantitative trait loci that confer heat resistance, introducing exogenous protective chemicals to seeds or plants, Using marker-assisted selection and field testing to screen the available germplasm; (6) Increase susceptibility to pests and diseases: stressed plants are more susceptible to pest & disease attacks, which can further reduce yield potential; (7) Integrated agronomic & genetic management techniques may increase wheat's resistance to heat.

Keywords: Detrimental, Sustainability, Translocation, Germplasm, Resistance

1. Introduction

For the majority of people on the planet, wheat (*Triticum aestivum* L.) is one of the most important cereal crops. It is the primary staple meal for about two billion people on the planet and contributes roughly 30% of the world's grain production and 50% of its grain trade. It provides a major contribution to the daily intake of fibre, calories, & micronutrients. Furthermore, it can be grown in a variety of climates and is very valuable to plant breeders. **(Karki *et al.*, 2021).** In India, the agricultural sector is crucial to the security of food, employment, and revenue. Roughly 66% of India's workforce is employed by it, and it contributes 14% of the country's GDP.

Wheat (*Triticum aestivum* L.), a cereal grass which belongs to the genus *Triticum* and family Poaceae, is the largest cereal crop in the world. It has a genomic size of 16 GB and a hexaploid (AABBDD) chromosomal number of 42 (2n=6x=42). Because of its great productivity, acreage, and significant position in the food grain trade, it has been referred to as the "King of Cereals." It can be grown in variety of soils and diversified climates than any other crop. **(Bhanu *et.al*., 2018)**. A wide range of agroclimatic zones are suitable for growing wheat; its ideal temperature is around 25°C, with minimum and maximum temperatures of 3.4°C and 33.2°C, respectively. **(Curtis 2002)**. According to FAO estimates, by 2050, the world wheat supply will need to reach approximately 840 million tonnes in order to meet the anticipated needs of nine billion people. Less land must be anticipated and available to meet this growing demand.

Climate changes, including high temperatures & erratic rainfall **(Sharma *et al.*, 2015).** In terms of both production and acreage, wheat is India's second-most important food crop, after rice. **(Ministry of Agriculture and Farmer Welfare, Govt. of India, 2022)**. Over 781 million metric tonnes of wheat were produced worldwide on an area of 222.7 mh. Almost all of the states in India and more than 85 other countries cultivate wheat. The country's need for wheat is growing every day. To meet the increased demand for wheat in the coming years, more acreage planted to wheat or higher yields per area will be needed. It makes up almost 12% of the world's wheat production. With an average productivity of 35.07q/ha from an area of 30.47 million ha, India's wheat output reached 112.74 mt and ranked second only to China in the world in 2022–2023; this accounted for 36% of the country's total production of food grains. **(Anonymous, 2022)**.

Heat-induced stress can affect wheat. Wheat yield is predicted to drop by 6% for each degree Celsius as the world temperature rises. Grain yield loss during the reproductive stage may rise by as much as 1°C over the mean temperature. **(Bennett *et al.*, 2012)**. Wheat is susceptible to a number of adverse effects from heat stress (HS), including reduced yield due to premature leaf senescence, decreased chlorophyll content, poor seed germination, decreased grain filling duration, decreased grain number, deactivation of Rubisco enzyme, decreased photosynthetic capacity, decreased rate of assimilate translocation, and decreased productivity. **(Hossain *et al.*, 2013)**. HS also affects the protein and starch content of grains. Reactive oxygen species (ROS), which are generated by HS, not only damage nucleic acids and cause lipid peroxidation and protein oxidation, but they also alter membrane stability. **(Mishra *et al.*, 2011)**.

The complicated phenomena of heat stress have an impact on physiological functions and inhibits growth and development. **(Mondal et al. 2013)**. Wheat's response to heat stress modifies its hormone synthesis. photosynthetic efficiency, metabolic processes and plant water relations **(Hasanuzzaman *et al.* 2013)**, growth of pollen tubes and pollen mortality. Reactive oxygen species also emerge at higher levels under heat stress and ethylene. Specifically, during the period of climate change, rising temperatures will have an effect on maintaining global wheat supply &, consequently, food security. **(Tripathi *et al.*, 2016)**. Increased temperatures have an impact on seed germination, which can lead to a reduction in grain size and quantity, poor plant stand, lower photosynthesis, membrane instability, senescence, and pollen viability. **(Asseng *et al.,* 2011)**. The cultivars and phenological stages have a major influence on how severe these effects are. Heat stress during blooming results in sterility of the pollen and anther, which reduces the quantity of grains; high temperatures coincide with the stage of grain filling, which reduces the weight of the grains and hence the yield. **(Mondal et al. 2013).**

There is a wide range of impacts that climate change has on crop productivity. (**Deryng *et al.,* 2014)** contributed significantly to our present understanding of how crops are affected by climate change in conditions of heat stress and high CO2. Heat stress is typically caused by a rising canopy temperature, which is influenced by the temperature of the air and soil, the properties of the soil, the canopy, and the soil moisture loss. The effect varies according to the phenological stages, cultivars, and crops. Understanding the effects of heat stress and potential methods for boosting heat tolerance as a result of global warming and alterations in climatic patterns is crucial for producing wheat in a heat-stressed environment. **Reidsma *et al.,* (2010)** examined different models of adaption strategies based on assessments of the consequences of global warming.

2. Impact of Heat Stress on Wheat

Wheat experiences significant yield loss due to the various growth and development stages being impacted by heat stress. The duration of exposure to heat and the growth stage during the elevated temperature, however, determine the effect of HS on the plant. **(Balla et al., 2012)** Poor germination, lower leaf area, early leaf senescence, and damaged photosynthetic machinery brought on by heat stress all contribute to diminished wheat photosynthesis. **(Asseng et al., 2015)**. Heat stress causes specific alterations in wheat morphology, physiology, and biochemistry. The length and intensity of heat stress as well as the crop's phenotypic stage determine how high temperatures affect wheat crops. **(Ruelland and Zachowski 2010).**

2.1 *Effect on wheat morphology and growth*

For several crops, including wheat, HS has a adverse effect on the growth and germination of seeds. **(Hossain et al., 2013).** Wheat seed germination and emergence are slowed when the temperature reaches or exceeds 45˚C because this affects embryonic cells. **(Essemine, Ammar, & Bouzid, 2010).** Heat stress primarily impacts the meristems of plants, lowering photosynthesis and encouraging leaf senescence and abscission to slow down plant growth **(Kosova et al. 2011)**. HS between 28 and 30°C can change how long plants develop by shortening the times it takes for seeds to germinate and mature. **(Yamamoto et al. 2008).** The productive tiller's capacity to live is impacted by high temperatures, which lowers output. There were fewer tillers (15.38%) and a poorer grain yield (53.57%) in wheat with HS. **(Din et al., 2010).** Reduced root growth due to HS eventually impacts agricultural productivity. **(Huang et al., 2012)**. The reproductive period is greatly impacted by heat stress. **(Nawaz et al., 2013)**. Increased grain yield loss during the reproductive stage could result from a 1°C increase in average temperature. **(Bennett et al., 2012).** Elevated temperatures cause mitochondrial degeneration, alter protein expression patterns, reduce the amount of ATP that builds up and the amount of oxygen that wheat embryos take in. Due to these impacts, there is a higher frequency of germination, mass, and vigour loss in seeds. **(Balla et al. 2012; Hampton et al. 2013).**

2.2 Effect on wheat physiology

2.2.1 *Water relations*

Changes in ambient temperature are often reported to cause the most instability in plant water status. A temperature of 31°C is typically thought to be the top limit at which a crop can retain its water status throughout blooming **(Atkinson and Urwin, 2012).** The general topic of water relations is how a plant controls a cell's hydration. It is dictated by properties like stomatal conductance and transpiration rate. The relationship between leaf water & stomatal conductance is disrupted by high temperatures. Heat stress can cause internal plant tissue to become dehydrated, which can further impede a plant's ability to develop **(Akter and Rafiqul Islam 2017).**

HS has a detrimental effect on root conductivity even when there is a sufficient amount of water in the soil, as shown by the wheat's lower leaf water content after being exposed to high temperatures. **(Morales et al. 2003).** Relative water content (RWC) dropping and water potential rising were among the physiological reactions of the flag leaf to terminal heat stress, and a decrease in turgor potential. **(Sattar et al. 2020).**

2.2.2 *Photosystems and photosynthesis*

As a C3 crop, Compared to C4 plants, wheat needs a lower optimum temperature for photosynthesis. Wheat grows poorly because photosynthesis is a physiological process that is sensitive to heat **(Feng et al. 2013).** A drop-in photosynthetic rate, early leaf senescence, and damage to the photosynthetic machinery are just a few of the detrimental effects that heat stress can have on wheat. **(Mathur et al. 2014).** The most delicate physiological process, photosynthesis, is the cause of wheat's poor growth performance. This is the result of early leaf mortality, decreased wheat production, reduced leaf area expansion, and an inadequate photosynthetic system. **(O'Neill et al., 2014).**

Reduced levels of photosynthetic pigments and reduced photosynthetic activity may be connected to heat stress-induced accelerated flag-leaf senescence. **(Balla et al. 2019).** Moreover, a reduction in stomatal conductance and net assimilation brought on by a drop in photosynthetic activity results in a prolonged heat stress duration. **(Balla et al. 2019).** A drop-in photochemical activity was linked to a decrease in photosynthetic assimilation. **(Chovancek et al. 2019)**.

2.3 Effect on grain growth and development

The optimal temperature range for wheat anthesis and grain filling is between 12 and 22°C. When temperatures above 24°C were experienced by plants while they were in the reproductive stage, their grain output significantly dropped, and the yield drop persisted as the exposure to high temperatures increased **(Nurunnaher et al., 2017).** At day/night temperatures of 32/22°C, wheat cultivars filled their grains more slowly than at 25/15°C. HS reduces assimilates & reduces nutrient remobilization. There was a significant relationship found between grain protein and leaf nitrogen levels **(Iqbal et al., 2017).** In order to allow for escape from high temperatures during the grain filling stage, the wheat variety intended for late planting should have a brief growing season. Heat stress affects grain size and quantity according to growth phases. Between the spike initiation stage & anthesis stage, if the temperature rises beyond 20°celcius, the spike will grow larger but produce fewer spikelets. **(Semenov & Halford, 2009).**

The wheat grain's entire dry weight, 60–75% is starch. While heat stress dramatically reduces the amount of starch that can be biosynthesised in wheat grains. found that applying heat shock treatment over 30°C significantly decreased the amount of dry matter that accumulated in wheat grains **(Sramkova et al. 2009).**

3. Management of Heat Stress

Wheat plants are negatively impacted by heat stress in terms of growth & development. With the help of different agronomic techniques and suitable plant genotypes, these impacts can be controlled. **(Asseng et al. 2011).**

3.1 Genetic management

Crops use breeding as a means of adaptability to their changing surroundings. In order to adapt to the conditions regarding potential climatic change, genetic diversity must be evaluated. In order to add new types to the systems of production, in order to address this, stress-inducible genes in genetic resources must be chosen and induced. **(Chapman et al. 2012).**

- ***Screening and breeding for heat tolerance***

Success using different physiological techniques has been demonstrated in breeding operations in Australia. Genetic resources are evaluated as part of the effort to determine the genetic foundations of crop heat tolerance. This allows the physiological crossover of novel trait combinations to be developed into desired new plant kinds that can be used to withstand future climate extremes, including high temperatures. **(Reynolds et al., 2016).** The selection criteria and screening methods used to find improved wheat genetic materials that are resistant of heat stress are usually focused on features associated with higher grain production in the unfavourable heat stress scenario.

- ***Biotechnical approach for improving heat tolerance***

Recent research has linked numerous transcription factors to different aspects of crops' ability to withstand abiotic stress **(Wani, 2020)**.

Genetic engineering and transgenic methods may be able to mitigate the harmful effects of heat stress by increasing heat tolerance. **(Chapman et al. 2012).** It includes introducing desirable genes into target plants in order to increase their resistance to HS. **(Zheng et al. 2012).** Studies on genetic modification in wheat are difficult, However, because of the complex genomic sequence.

3.2 Agronomic management

By applying and modifying particular agronomical procedures, it is possible to cultivate wheat and many other crops in warm weather. These methods include selecting the proper cultivar, timing and spacing seeds, using growth regulators, helpful microbes, and exogenous protectants.

3.2.1 *Conserving soil moisture*

To keep wheat grains at the proper length, size, and rate of filling, a steady supply of water is required. This might not be possible in regions that produce wheat from rain, but in these situations, The best way to keep the right soil moisture and temperature regimes might be through mulching. By lowering soil evaporation, straw mulch helps to retain soil moisture. **(Chen et al. 2007).**

3.2.2 *Timing of planting and nutrient management*

Plants that are stressed by temperature need a sufficient and well-balanced supply of mineral nutrients. **(Waraich et al. 2012).** Grain proteins are enhanced by the application of NPK throughout the postanthesis stage while day and night temperatures stay at 24 and 17° celcius, respectively. However, Higher temperatures during the day and at night neutralise the effects. Nutrient foliar spraying is a very effective way to lessen the damaging effects of HS on wheat.

3.2.4 *Bacterial seed treatment*

Breeding initiative implementation is expensive and time-consuming, and many stakeholders hold unfavourable views on gene modification technologies. As a result, using biological control agents like bacteria and fungi is currently thought to be a different approach to increase one's capacity for heat. **(Raaijmakers et al. 2009).** Wheat's ability to withstand heat was increased by foliar spraying a variety of organic and inorganic chemicals and treating the seeds with rhizobacteria **(Yang et al. 2009).**

CONCLUSION

A major grain crop that is consumed by most people worldwide is wheat. However, heat stress has become a major obstacle to wheat production as temperatures rise in the current climate change scenario. Heat stress has a negative impact on grain development, pollination, root growth, and photosynthesis. It interferes with the physiological process and proper grain development by affecting the activities of vital enzymes, the metabolism of carbohydrates, and the synthesis of protein in grains. It is known to cause the plant to reach the reproductive phase earlier and complete its vegetative phase. In the end, these effects result in a decrease in yield. Therefore, by being conscious of these consequences, we can find different ways to reduce the impact that unfavourable growth conditions have on plant output. To address the various complications of heat stress, appropriate agronomic management techniques in conjunction with both traditional and contemporary molecular genetics technologies can be beneficial.

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