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# Terminal Heat Stress in Wheat: Its Causes, Effects & Management Strategies

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**SUMMARY**

Wheat (*Triticum aestivum* L.) is the most famous cereal crop grown by the vast majority of the world's population. Common bread wheat is accepted by more than 2 billion people worldwide as a staple food. Wheat produces about 55% of all carbohydrates and 20% of all dietary calories in the globe. Heat stress is the main limiting factors for wheat production worldwide. The effect of climate change is being observed in India in the form of shorter winter coupled with commencement of summer quite earlier than normal. Raising of temperature above 31°C during grain filling causes heat stress. Every 1°C rise in temperature reduced the wheat production by 6%. Heat stress disrupt the plant water relation, cell turgidity, reduced seed germination and seedling growth, deactivation of photosynthetic enzymes, disturb translocation of photosynthate due to which it reduced grain number and grain filling. Effective approaches for managing heat stress in wheat include screening available germplasm under field trials and/or employing marker-assisted selection, application of exogenous protectants to seeds or plants, mapping quantitative trait locus conferring heat resistance and breeding. A well-integrated genetic and agronomic management option may enhance wheat tolerance to heat. Adaptation of these strategies will help in reducing impact of heat stress by 7.5, 6.4 and 9% respectively in present, 2020 and 2050 heat stressed scenarios.

## INTRODUCTION

Contemporary agriculture faces a tremendous environmental pressure across the globe. Various environmental stresses affecting plant growth and development have attained a serious concern in the context of possible climate change. However, the most remarkable environmental concern in agriculture is the increase of global temperature. With regard to global climate models, the mean ambient temperature is predicted to increase by 1–6°C by the end of twenty-first century. Such increase of global temperature may have a significant influence on agricultural productivity in accordance with the severity of the high temperature, drought, salinity, waterlogging, and mineral toxicity stresses. High temperature-induced heat stress is expressed as the rise in air temperature beyond a threshold level for a period sufficient to cause injury or irremediable damage of crop plants in general. The heat stress situation is aggravated when soil temperature increases as a result of increase in air temperature associated with decline in soil moisture. Thus, heat stress has appeared as a great menace to successful crop production in the world.

### Importance of Wheat

Wheat (*Triticum aestivum* L.) is a globally cultivated cereal crop, feeding about 37% of world's population with nearly 3 billion consumers spread in 124 countries (FAO STAT, 2020; Erenstein *et al.*, 2022). Wheat serves as staple food in most of the countries producing it by virtue of its large-scale production, high productivity and satisfactory nutritional value. The effect of climate change is being observed in India in the form of shorter winter coupled with commencement of summer quite earlier than normal. Heat stress is the main limiting factors for wheat production worldwide. The proximity of equator and late sowing of wheat (due to late harvesting of rice) exposes the wheat crop (*Triticum aestivum* L.) to high temperature stress during grain filling stage leading to terminal heat stress in the crop and reduced yield. Raising of temperature above 31°C during grain filling causes heat stress. Every 1°C rise in temperature reduced the wheat production by 6%.

### Heat stress in Wheat

The rise in temperature beyond a certain threshold level for a period sufficient to induce irreversible damage to plant growth and development is referred to as heat stress. Heat stress is major constraint of bread wheat (*Triticum aestivum* L) growth and development, decreasing yields by 3 to 5% per 1°C rise above 15°C in plants under controlled conditions. Since there is rise in temperature during grain filling period, terminal heat stress has significant effects on all traits such as grain yield and yield components of spring bread wheat cultivars. Wheat is sensitive to high temperature during reproductive stage as compare to vegetative stages. For each degree

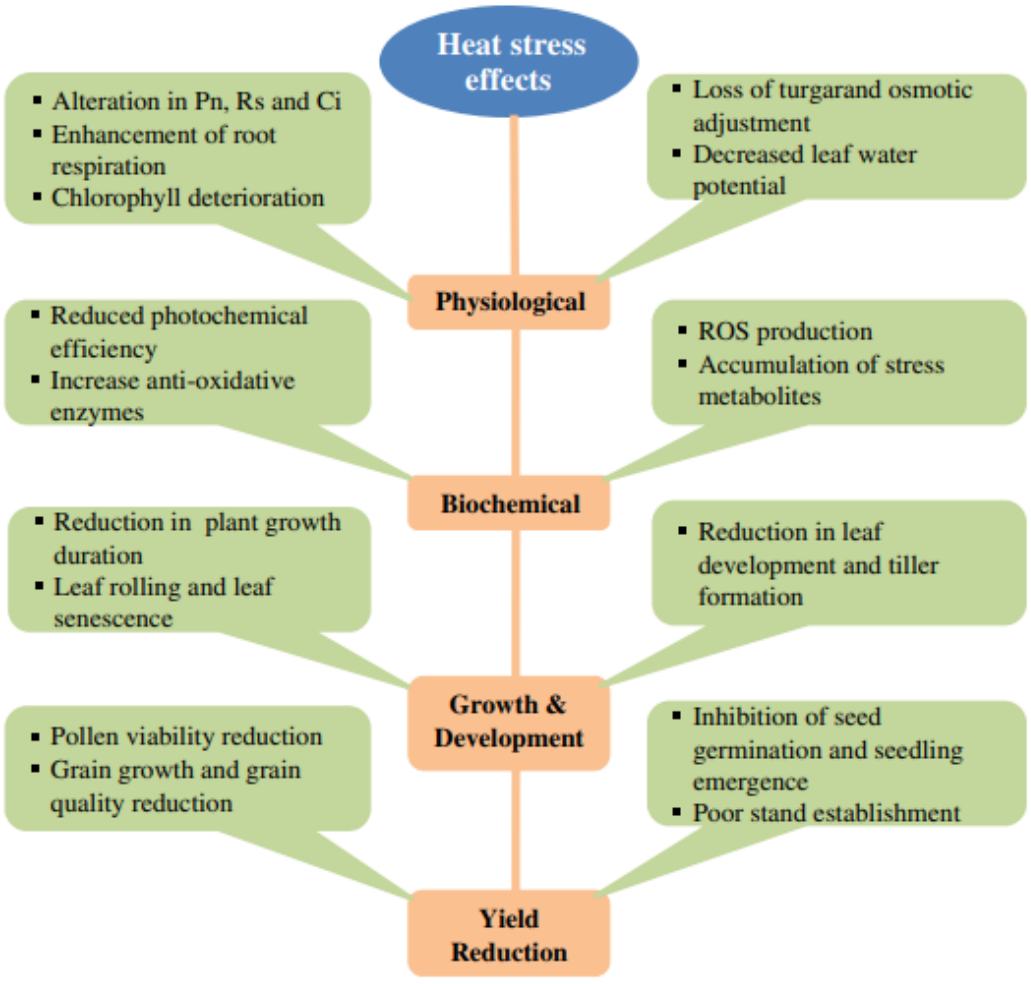
rise in temperature, wheat production is estimated to reduce by 6%. Terminal heat stress will reduce wheat yield by 18.1%, 16.1% and 11.1%, respectively in present, 2020 and 2050 scenarios. It disrupts the plant water relation, cell turgidity, reduced seed germination and seedling growth, deactivation of photosynthetic enzymes, disturb translocation of photosynthate due to which it reduced grain number and grain filling.

**Causes of heat stress**

- **Climatic Variation**: Average global temperatures are predicted to rise by about $20^0$C over the next 50 years, making many cereals growing regions even less suitable, based on predicted temperature range. Such increase of global temperature may have a significant influence on agricultural productivity in accordance with the severity of the high temperature, drought, salinity, waterlogging, and mineral toxicity stresses. High temperature-induced heat stress is expressed as the rise in air temperature beyond a threshold level for a period sufficient to cause injury or irremediable damage of crop plants in general.
- **Late sowing**: Different studies demonstrate that delayed sowing increases the probability to occurring terminal heat stress during grain filling stage which significantly reduces grain yield. The timely sowing in the period between 15 and 25 November may be advocated to avoid terminal heat stress in wheat in the IGP region. Each day delay in sowing of wheat after 30th November on ward decreases grain yield at the rate of 36 kg/ha/day.

**Effects of Heat Stress**

Wheat is a thermo-sensitive crop mostly grown in temperate environment. However, it is predominantly consumed in tropical and subtropical regions of the world. Heat stress is one of the major limiting factors for growth and productivity in wheat crop particularly in warmer region. Exposure to higher-than-normal temperature or heat stress reduces yield and decreases quality. More than 40% of total wheat area in the world is affected by

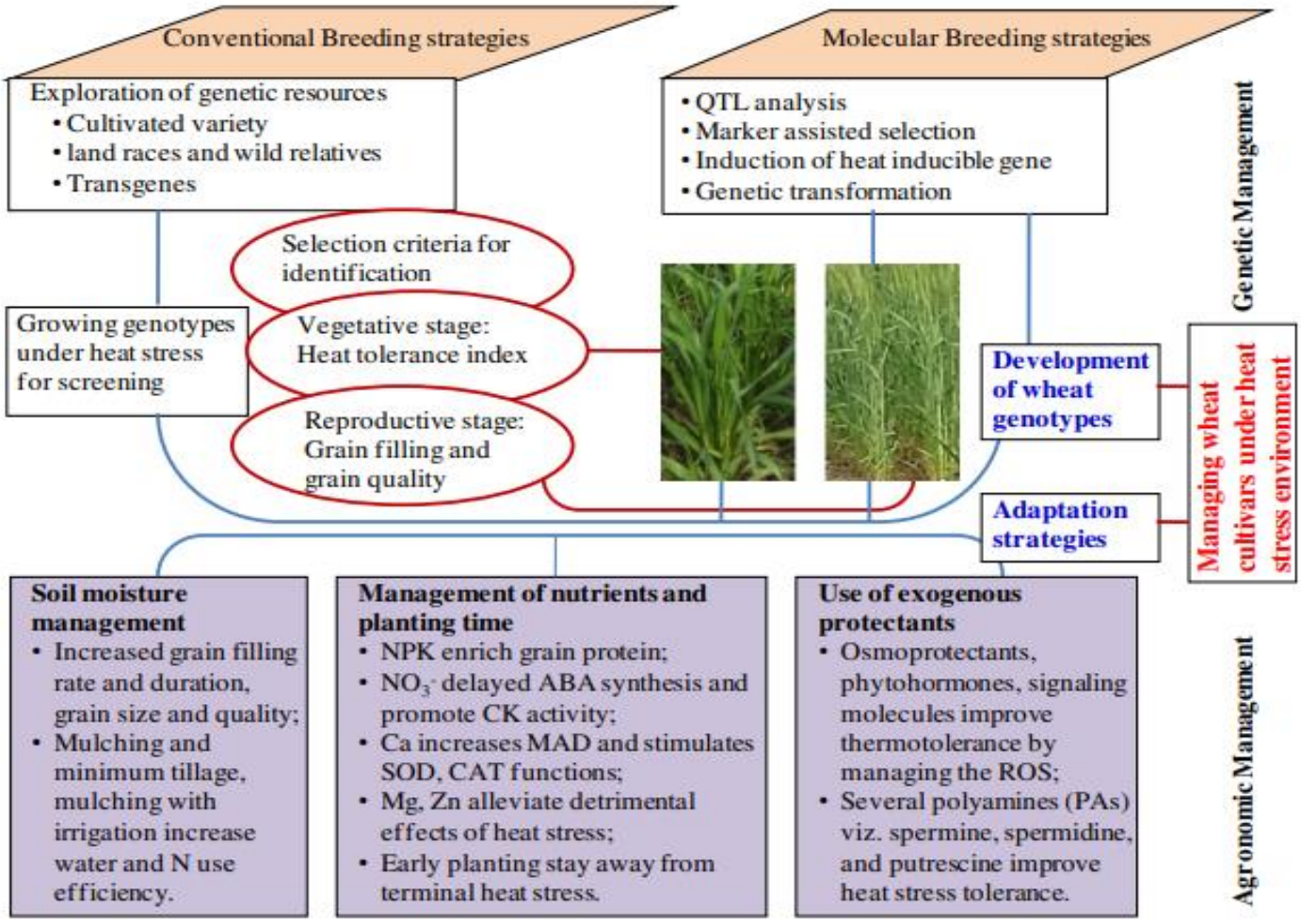


high temperature stress. High temperature stress induces several alterations in physiological, biochemical and molecular components of wheat crop production.

- Heat stress significantly reduces seed germination and seedling growth, cell turgidity, and plant water-use efficiency
- At a cellular level, heat stress disturbs cellular functions through generating excessive reactive oxygen species, leading to oxidative stress
- The major responses of wheat to heat stress include the enhancement of leaf senescence, reduction of photosynthesis, deactivation of photosynthetic enzymes, and generation of oxidative damages to the chloroplasts
- Heat stress also reduces grain number and size by affecting grain setting, assimilate translocation and duration and growth rate of grains

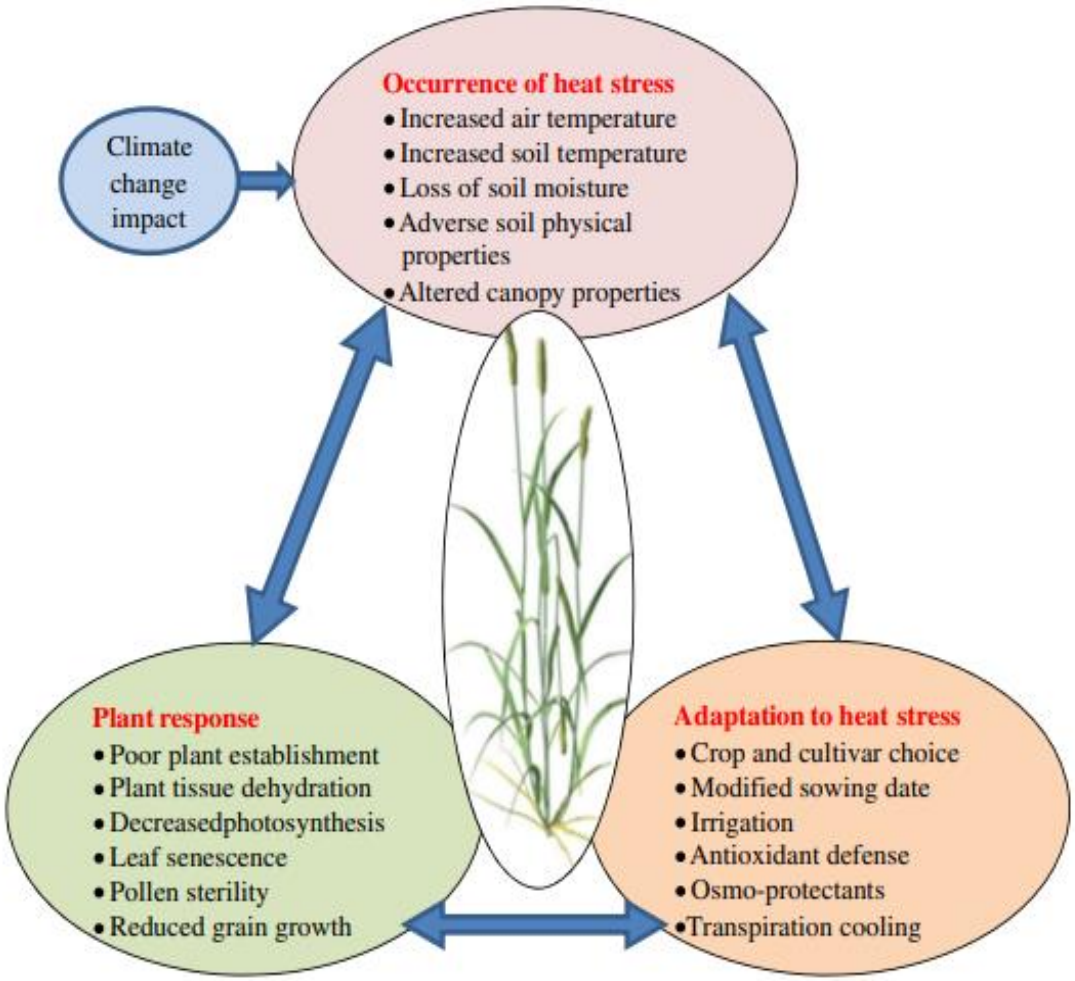
**Management of heat stress in wheat**

Advancement in sowing date, application of additional dose of nitrogen and irrigation at grain filling stage were found suitable options for preventing yield loss in wheat due to heat stress. Management approaches like agronomic management and genetic management can be applied against heat stress.




- **Agronomic Management:** Wheat can be grown successfully in a warmer environment through manipulating some agronomic management practices. Adoption of various agronomic practices like (i) water conserve techniques (ii) the appropriate amount and methods of fertilization (iii) maintaining proper time and methods of sowing, and (iv) the application of exogenous protectants can effectively alleviate the adverse impact of heat stress in wheat.

- **Water Conservation techniques:** A continuous supply of water is necessary for sustaining the grain filling rate and duration, and grain size in wheat. This could not be possible in rain-fed wheat growing area, but here, mulching can be the best option for maintaining optimum moisture and thermal regimes in the soil system. Straw mulch conserves soil moisture by reducing soil evaporation (Chen *et al*., 2007). However, mulching is advocated to avoid yield reduction in wheat when reduced tillage is practiced.
- **Appropriate amount and method of fertilization:** Adequate and balanced supply of mineral nutrients is essential in plants exposed to temperature stress. The exogenous application of calcium promotes heat tolerance in plants.
- **Bacterial seed treatment:** Using biological control agents like fungi and bacteria are now considered as an alternative method of improving heat tolerance. Plant growth-promoting rhizobacteria are found to be compatible and having a beneficial effect on the growth of wheat plants under heat stress. Seed treatment with rhizobacteria and foliar spray of various organic and inorganic agents enhanced heat tolerance in wheat. Seed inoculation with rhizobacteria also significantly improved heat tolerance in wheat.
- **Use of exo-protection**: In recent times, exogenously applied several growth promoting protectants such as osmoprotectants, phytohormones, signaling molecules and trace elements have resulted in the potential to protect the plants by neutralizing the harmful and adverse effects of heat stress. Exogenously applications of these substances improve thermotolerance in wheat under heat stress by managing the ROS (Farooq *et al*. B. H., 2011) and up regulating the antioxidant capacity (Hemantaranjan *et al*., 2014).
- **Genetic management**: Breeding is an adaptation response of crops under changing environment. Therefore, it requires the evaluation of genetic diversity for adaptation to future climate change conditions, and thereby the selection and induction of stress inducible genes of genetic resources for developing new varieties in the production systems. Breeding for heat tolerance is still in the preliminary stage and therefore much attention



is given to the genetic improvement of wheat to heat stress. In recent years, several studies have been done to find out wheat genotypes tolerant to heat stress.

## CONCLUSION

Heat stress was found to lead to enormous loss of wheat productivity worldwide. Wheat shows various physiological and morphological response towards it. For fighting towards heat stress plant lost its yield at very huge quantity. Effective approaches for managing heat stress in wheat include screening available germplasm under field trials and/or employing marker-assisted selection, application of exogenous protectants to seeds or plants, mapping quantitative trait locus conferring heat resistance and breeding and a well-integrated genetic and agronomic management option may enhance wheat tolerance to heat.

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