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IMPACT OF HIGH TEMPERATURE ON WHEAT (TRITICUM AESTIVUM) CROP - REVIEW

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ABSTRACT

Wheat (Triticum aestivum L.) is one of the most important staple crops in the world. However, rising global temperatures due to climate change have a significant effect on wheat productivity. Wheat is a temperate cereal crop, particularly sensitive to heat stress during key developmental stages, including germination, flowering, and grain filling. Elevated temperatures impair physiological and reproductive processes, leading to reductions in seed germination, tillering, pollen viability, and grain filling duration. Studies indicate that temperatures exceeding optimal thresholds (particularly above 30–32°C) significantly reduce kernel number and weight, spikelet fertility, and ultimately yield. High temperatures disrupt photosynthesis by damaging chlorophyll and carotenoid content and reducing grain quality by affecting starch and protein synthesis. Understanding genotype-specific responses and mechanisms of heat stress tolerance is essential for developing climate-resilient wheat varieties. This review synthesizes the effects of high temperature on wheatgrowth stages, yield traits, and offering insights into breeding strategies.

Keywords: Wheat, High Temperature, Climate, Vegetative Stage, Reproductive Stage

1. INTRODUCTION

Climate change has widespread and profound impacts on global agriculture. The rise in global temperatures has led to changes in climate patterns, climate change has caused sea level rise, glacier melting, and ecosystem changes, creating various pressures on global agriculture. Within global agriculture, wheat holds a unique and crucial position. Wheat (Triticum aestivum L.), an important staple food crop, grown in aired and semiarid areas worldwide. Wheat grains are rich in essential elements and a major source of nutrition as a vital source of carbohydrates and proteins, wheat accounts for 13% of global production, with India contributing significantly. However, recurrent heatwaves and high temperature have caused yield reductions up to 25%, particularly in the northwestern plains, including Punjab a key wheat-growing region. Heat stress is defined by a mean daily temperature of over 17.5 °C in the coolest month of the season and over 50 countries experience this type of stress throughout the wheat growth cycle. In addition, it has been anticipated that intensity and frequency of heatwaves will continue to increase through the 21st century, and the global land area facing heatwaves will be four times by 2040. Precisely continuous increase in heatwaves have contributed to a 0.5 ∘ C increase in mean global temperature, which have a severe impact on growth, yield and product quality of crops (Mishra et al

2021).Global population growth, projected to reach 10 billion by 2050, further exacerbates the challenge of meeting wheat demand, necessitating adaptive strategies to enhance heat-stress tolerance. Wheat (Triticum aestivum L.) is a temperate cereal with an optimumtemperatureregimeof15–18°Cduringthegrainfillingstagebut daily high temperature of 25–35°C or greater is common across manyregions oftheworld wherewheatisgrown(Modarresi et al 2010). Although different species and cultivars to high temperatures may vary with the stage of plant development, all vegetative and reproductive stages are affected by heat stress to some extent (Wahid et al 2007). High temperature can reduce the crop yield by reducing the kernel number and kernel weight. The responses of these yield components to temperature varied with timing and duration of treatments and among cultivars. Temperatures as high as 30/258C decreased kernel number up to 22%andkernel weight by as much as38% and a greater increase in temperature from 20/16 to 36/318C from 7 d after anthesis until ripeness decreased kernel weight up to 85% (Gibson and Paulsen 1999).According to Joshi et al (2007) as per estimates the global mean temperature is steadily rising which may result in significant decline in wheat yields in South Asia by 2050. The 2022 heatwave was the hottest March in over 120 years, leading to prolonged exposure to high temperatures during crucial wheat development stages. This heatwave, which struck during critical wheat growth phases in March and April, is estimated to have reduced national wheat yields by 4.5% compared to normal climate years (1992–2021 average), with some districts experiencing losses of up to 15% (Sidhu 2023). Understanding how high temperatures affect wheat at different developmental stages is critical for developing heat-resilient genotypes.

2. EFFECT OF HIGH TEMPERATURE ON WHEAT

It has found that rising temperature had negative effect on wheat yield and productivity in the tropical, subtropical and semi-arid regions of the world (Khan et al 2021). Both high and low temperatures decrease the rate of dry matter production and may stop production. Temperatures that lie outside the range of those typically experienced can have severe consequences for crops, significantly reducing yields. It seems to be the case that plants respond to absolute rather than relative changes in temperature, i.e. there are discontinuous threshold responses to temperature (Porter et al 1999). Higher temperatures affect all phases of crop growth. They accelerate floral initiation and reduce the period of spike development, resulting in shorter spike with lower number of spikelets. Additionally,they adversely affecting pollen development. (Modarresiet al 2010). According to Begum et al (2014) wheat plant grown under 25 ˚C took 98-99 days to complete its life cycle. So, under temperature stress conditions the crop production was reduced. The high temperature of the day can damage the leaf photosynthesis components, reducing the rate of CO2 assimilation during the vegetative process compared to the optimal temperature setting. Heat stress inhibits the development of plants both throughout the plant growth and reproduction phases (Farhad et al 2023). High temperature stress affects wheat yield by Reducing pollen viability and grain set during anthesis and altering the balance of carbohydrate and protein synthesis (Nuttall et al 2018).

3. EFFECT OF HIGH TEMPERATURE ON GERMINATION STAGE AND SEEDLING STAGE

High temperatures can impact germination rate, seedling vigour, and early root development, affecting plant establishment. High temperature particularly during November season, accelerates sowing and making the crop to enter into jointing stage too early that reducing the tillering period (Kajlaet al 2015). The rate of stem elongation is lower in the vegetative phase than in the reproductive phase with rapid stem growth beginning shortly after the terminal spikelet stage of the main shoot apex. Stem elongation is slower at temperatures below 20°C during the vegetative phase. Several studies have investigated the influence of temperature on leaf initiation and emergence. In the most comprehensive study, we found 42 wheat varieties were studied under a variety of temperature regimes to identify minimum temperature for leaf initiation, a value found to be 2.5°C. Temperatures higher than 25°C have been found to inhibit leaf appearance. Cooler minimum temperature values were found for four Australian cultivars for which an average temperature of about −4°C was identified (Porter et al 1999).

Leaf senescence is the reduction in green leaf area during the reproductive phase due to the retardation in the chlorophyll content and carotenoids. The chlorophyll content and carotenoid have an essential role in photosynthesis. High temperature disturbs the chloroplast integrity, leaf senescence, and ultimately photosynthesis in wheat. Leaf senescence degrades the leaf chlorophyll content during grain filling stage. Chlorophyll deficiency reduces the absorbance of light energy. High temperature reduces the end use of protein quality which is more or less dependent on the grain protein concentration (Khanet al 2021).

4. EFFECT OF HIGH TEMPERATURE ON REPRODUCTIVE STAGE

All the physiological processes of wheat plants are sensitive to temperature and can be damaged by heat permanently. Heat stress during anthesis can increase floret abortion and temperatures over 30 °C during floret formation may lead to complete sterility. Heat stress during reproductive stage can lead to pollen sterility, tissue dehydration, lower CO2assimilation, increased photorespiration and reduced time to capture resources due to accelerated growth and senescence, consequently reducing the yield (Wang et al 2021). Ideally the best temperature regime for optimum growth and yield of wheat crop is: 20–22 °C at sowing, 16–22 °C at tillering to grain filling and slow rise of temperature to 40 C at harvesting (Kajla et al 2015). High temperature after flowering hastens leaf senescence, thereby reduces grain filling stage and thus decreases grain yield. An increase of 0.5 °C temperature resulted in decrease in duration of crop by seven days, reducing yield in north India (Kajlaet al 2015). Temperatures above 31°C immediately before anthesis reduces grain yield by inducing pollen sterility, thus reducing grain numbers. Temperatures above 31°C for the five days prior to anthesis resulted in a high number of sterile grains (Porter et al 1999). Similarly, Tashiro and Wardlaw (1990) found that temperatures of 36°C during the day and 31°C at night just before anthesis resulted in a many sterile grains. Shortened grain filling duration and reduced starch accumulation directly impact grain weight. Heat stress (with a 3.9C increase in night temperature over ambient) coinciding with anthesis in field-grown wheat reduced grain yield by 7% per °C increase in night temperature, with the reduction in grain yield mainly attributed to a lower number of spikes per meter square (Impa et al 2021). Nuttall et al (2018) investigated acute heat wave events (>32°C) applied during pre-anthesis and post-anthesis periods. They found grain number and yield were reduced by 0.16% and 0.15% per °C×h of heat load when heat was applied 5 days before anthesis. After anthesis, grain weight declined by 0.05% per °C×h, indicating grain filling is highly sensitive to short-term heat exposure. Interestingly, grain nitrogen concentration increased, possibly due to reduced starch deposition. Mamrutha et al (2020) study shows that High night temperature during grain filling is the most detrimental, aligning with global findings that high night temperatures shorten grain-filling duration and reduce starch accumulation. Physiological resilience at vegetative stages can buffer initial high night temperature, but not at reproductive stages.

5. IMPACT ON YIELD AND YIELD-RELATED TRAITS

High temperatures can lead to lower individual grain weight and reduced seed numbers, which are critical for overall yield. Heat during flowering reduces fertile florets and pollen sterility, decreasing grains per spike (Prasad & Djanaguiraman, 2014). Heat shortens grain filling duration, reducing weight by 15–30% (Nicolas&Stone, 1995).Gibeson and Gibson et al (1999) studied winter wheat cultivar karl 92. These wheat plants were grown in greenhouse conditions and then moved to growth chambers at 10 days post-anthesis. Four temperature treatments were applied: 20/20°C, 25/20°C, 30/20°C, and 35/20°C (day/night). These conditions were maintained until grain ripeness. Vegetative Weight decreased by 55 mg per plant for each 1°C increase above 20°C while Kernels per Spike: Dropped by 2 kernels per 1°C increase from 22.5°C to 27.5°C. Grain Yield per plant decreased by 268 mg per °C and grain yield per spike decreased by 62 mg per °C while Kernel Weight: Showed a curvilinear decrease, with a total reduction of 7.5 mg at the highest temperature (27.5°C mean) compared to 20°C.Modarresiet al (2010) studied 144 recombinant inbred lines (RILs) from a cross between a heat-tolerant (Kauz) and a susceptible (MTRWA116) wheat parent, along with 8 commercial cultivars, over two years were grown under normal and heat stress (late sowing) conditions. Heat stress significantly reduced all measured traits, with grain yield, 1000-kernel weight. The study confirms that heat stress, especially during grain filling, accelerates senescence and reduces kernel weight and yield. Under high temperatures, wheat may experience phenomena such as another abscission and reduced pollen vitality, resulting in a decrease in pollen quantity and pollination rate, ultimately affecting grain formation. This could lead to a reduction in wheat yield. Additionally, as high temperatures can affect the synthesis of starch and proteins, the quality of wheat may also be compromised, manifesting as weakened gluten strength and overall quality decline(Yanagi 2024). Hossain et al (2012) conducted field trials under late sowing to simulate heat stress and reported yield reductions of 46% in 'Sourav', a heat-sensitive variety. Only 27% in 'Shatabdi', highlighting genetic variability in heat tolerance. Heat stress shortened phenological phases and reduced growth parameters such as plant height and biomass. This varietal screening provides valuable input for breeding programs aimed at improving thermo-tolerance. Similarly, Kaur and Behl (2010) conducted controlled experiments on two wheat varieties WH730 (tolerant) and UP2565 (sensitive) under short durations of high temperature, drought, and their combination during booting and post-anthesis stages. Results showed additive and synergistic yield reductions under combined stress, with more severe impacts at post-anthesis. WH730 exhibit greater heat tolerance than UP2565 as evidence by higher grain number and weight, longer grain filling duration. Understanding the genetic variability and mechanisms underlying heat tolerance can play a crucial role in sustaining wheat productivity under future climate scenarios.

6. CONCLUSION

The rising global temperatures and increasing frequency of heatwaves pose a significant impact to wheat production, particularly in tropical, subtropical, and semi-arid regions. Wheat, being a cool-season crop, is highly sensitive to elevated temperatures, especially during critical growth phases such as germination, flowering, and grain filling. High temperatures negatively impact germination rates, seedling vigour, spikelet formation, pollen viability, and grain filling duration leading to substantial reductions in grain number and weight. Studies have consistently shown that even a small increase in temperature can result in dramatic yield losses, with reductions in kernel weight under extreme heat stress. Furthermore, heat stress accelerates leaf senescence, disrupts chloroplast function, and diminishes photosynthetic efficiency, ultimately affecting grain quality. Future research should focus on high-throughput phenotyping, functional genomics, and climate-smart agriculture to ensure sustainable wheat production.

CONFLICT OF INTERESTS

None.

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