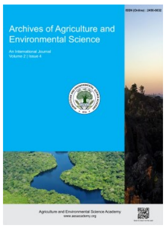
Archives of Agriculture and Environmental Science 6(3): 381-384 (2021)
https://doi.org/10.26832/24566632.2021.0603018

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



REVIEW ARTICLE

# A review on the effect of heat stress in wheat (*Triticum aestivum* L.)

**Preeti Karki, Enzy Subedi, Garima Acharya*, Manisha Bashyal, Nistha Dawadee and Srijana Bhattarai**

Institute of Agriculture and Animal Science, Tribhuvan University, Rupandehi, NEPAL
*Corresponding author's E-mail: garimaacharya109@gmail.com

**ARTICLE HISTORY**

Received: 19 July 2021
Revised received: 30 August 2021
Accepted: 22 September 2021

**Keywords**

Crop yield
Heat stress
Wheat (*Triticum aestivum*)
Photosynthesis

**ABSTRACT**

Wheat is one of the most important cereal crops in the world. It ranks first (in the world) and third (in Nepal) in terms of productivity and total cropped area. Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories. The ideal temperature for its cultivation is about 15°-20°C. Among several abiotic factors, heat stress is one of the major factors affecting wheat production. Wheat is very sensitive to heat stress. Each degree rise in the temperature can decrease wheat yield by 6%. This review is written with an aim to reflect the influence of heat stress in the production of wheat and the mechanism of how loss in yield occurs. Some of the major findings of this research are : (a) Heat stress negatively effects germination, emergence, root growth, leaf, stem development and growth, tillering, grain yield and quality (b) A sharp decline in photosynthesis is evident when wheat plant is exposed to high temperature stress during vegetative or reproductive phase (c) With increases in temperature, rate of respiration is greater than the rate of photosynthesis which ultimately leads to carbon starvation (d) High temperature fastens the crop growth by making it to enter into jointing stage and reproductive stage earlier than normal resulting in decreased crop yield. The identification of such effects of heat stress in our crop helps us adopt several strategies or methods to mitigate the impacts on crop yields and improve tolerance to heat stress.



**Citation of this article:** Karki, P., Subedi, E., Acharya, G., Bashyal, M., Dawadee, N., & Bhattarai, S. (2021). A review on the effect of heat stress in wheat (*Triticum aestivum* L.). *Archives of Agriculture and Environmental Science*, *6*(3), 381-384, https://dx.doi.org/10.26832/24566632.2021.060018

## INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops for the majority of world's populations. It is considered as a major staple food of about two billion people worldwide and contributes about 30% of world grain production and 50% of the world grain trade. It provides a significant contribution to daily energy, fiber and micronutrient consumption. Also, it is cultivated over a wide range of climatic conditions and is of great value for plant breeders. Wheat belongs to family Poaceae along with major crop plants such as barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), rye (*Secale cereale* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Wheat production is affected by various unpredictable biotic and abiotic factors. Globally, around 9% of the area is suitable for production of food crop, out of which 91% is under different stresses. According to world estimates, an average of 50% yield losses in agricultural crops are due to abiotic factors like high temperature (20%), low temperature (7%), salinity (10%), drought (9%) and other forms of stresses (4%) (Kajla *et al*., 2015). This review focuses on the effect of heat stress in wheat. Here we have discussed about how impacts are created on molecular, physiological and morphological processes of wheat. Wheat is a crop susceptible to higher temperature (Akter and Rafiqul Islam, 2017) so heat stress has emerged as one of the severe abiotic threats in wheat production in many of the countries around the world. The continuous rising temperature under climate change, that induces heat stress effects on crops, has become a major concern in agricultural sector. According to global climate model, the mean temperature is estimated to increase by 6°C at the end of 21st century (De Costa, 2011).

It is also estimated that 1°C increase in temperature causes decrease in global wheat production by 6% (Asseng *et al*., 2015). Heat stress results in morpho-physiological alterations in wheat plants, hindering the development processes and eventually leading into great yield loss (Lin *et al*., 2019).

## EFFECT OF HEAT STRESS ON PHYSIOLOGICAL PROCESSES

### Water relation

Temperature of 31°C is generally considered as an upper limit of maintaining water status of a crop (Atkinson and Urwin, 2012). High temperature causes dehydration in plant tissue which ceases the growth and development of plants. Heat stress increases the soil water content threshold (i.e., the amount of water that the plant can extract) (Haworth *et al*., 2018). There will be increase in the rate of evapotranspiration due to higher vapour pressure deficits in higher temperature condition (Muhammad *et al*., 2011).

### Photosynthesis

Like any other plants, photosynthesis is one of the most sensitive process in wheat (Al-Khatib and Paulsen, 1984). The optimum temperature for photosynthesis in wheat is around 20 to 30°C, and the rate of photosynthesis declines rapidly at temperatures above 30°C (Narayanan, 2018). The heat labile cell components are thylakoid membrane and PS-II. The damage to thylakoid by heat leads to chlorophyll loss (Ni *et al*., 2018). Heat stress causes higher degradation in chlorophyll than other abiotic stress like drought stress. It decreases photosynthesis rate through disruptions in the structure and function of chloroplasts, reduction in chlorophyll content and inactivation of chloroplast enzymes, decrease in leaf area expansion and premature leaf senescence which ultimately results in reduction of yield (Akter and Rafiqul Islam, 2017; Narayanan, 2018). High temperature result in the decreased solubility of $O_2$ and $CO_2$ however, increased photorespiration and lower photosynthesis.Researchers believe that heat stress reduces solubility of proteins, Rubisco and Rubisco binding proteins resulting in suppression of carbon assimilation (Parry *et al*., 2011) Photosystem II is more responsive to heat stress than photosystem I (Marutani *et al*., 2012).This may in turn result in inhibition of photosystem II activity, which has been shown to be the most thermally labile component of the photosynthetic electron transport chain (Feng *et al*., 2014; Mathur *et al*., 2011).

### Respiration

Heat stress brings changes in mitochondrial activities by affecting respiration. Increase in temperature increases rate of respiration, but at a certain level of temperature, it diminishes due to damage of respiratory apparatus (Akter and Rafiqul Islam, 2017). The rate of respiration increases with increase in temperature and reach to the point where the rate of photosynthesises cannot compensate the respiratory losses and leads to the carbon starvation (Narayanan, 2018).

### Biochemical effect

High temperature stress often favours accumulation of reactive oxygen species (ROS) such as hydrogen peroxide ($H_2O_2$ ), superoxide radical ($O^{2-}$), hydroxyl ion ($OH^-$) and oxygen ($O^{-1}$) in plant tissues (Lai and He, 2016). The reactive oxygen species generated due to stress in chloroplast ,mitochondria and peroxisome can disrupt the normal metabolism through oxidative damage of proteins, lipids and nucleic acid leading to damage of cell structure (Qaseem *et al*., 2019). Starch ,which is the major constituent of wheat is composed of amylose and amylopectin. This starch content in grain is reduced up to one-third of total endosperm starch at high temperature because of decreased efficiency of enzymes involved in starch biosynthesis (Feng *et al*., 2014).

## EFFECT OF HEAT STRESS ON MORPHOLOGICAL AND PHENOLOGICAL PROCESS

Heat stress adversely effects germination, emergence, root growth, leaf, stem development and growth, tiller, dry matter production, floral initiation, panicle exertion, pollination, fertilization, seed growth, seed yield and seed quality (Huang *et al*., 2012; Iqbal *et al*., 2017). Under constant soil moisture condition, seed germination percentage increases above base temperature and decreases above the optimum level (Prasad *et al*., 2006). In wheat, heat stress usually decreases growth stage duration from emergence to anthesis (Narayanan, 2018). Higher temperature fastens the crop growth by making it to enter into jointing stage and reproductive stage earlier than normal, thus reducing tillering period. This leads to reduction in number of tillers, in turn reducing total crop yield (Kajla *et al*., 2015; Khan *et al*., 2020). Heat stress negatively affects pollen cell and microspore resulting into male sterility (Anjum *et al*., 2008). A major limitation to wheat production in most parts of the world is high temperature stress during reproductive development (Wollenweber *et al*., 2003). Although wheat experiences different degree of impacts during different phenological stages, the stress during reproductive stage is considered to be more harmful. This is because there is a direct impact on grain number and grain filling that ultimately causes reduction in wheat yield and lowers the quality. Rate of grain filling is accelerated under heat stress which shortens the grain-filling duration (Dias and Lidon, 2009). It also causes reduced grain size leading to reduction in thousand grain weight of wheat (Zhang *et al*., 2017).

In a field research conducted at Bhairahawa, Nepal in 2016/17 by (Poudel *et al*., 2020), the physio-morphological and yield potential trait associated with heat tolerance in wheat genotypes was determined. The plant material consisted of 20 genotypes among which 17 were advanced and 3 were commercial varieties of Nepal. The mean grain yield under heat stress was 1793.65 kg/ha. There was highly significant difference in days to maturity and days to heading. The mean number of days to maturity under heat stress was found to be 99.25 while the days to maturity for wheat under normal condition is about 120 to 125 days. The mean number of days to heading was found to be 60.8 days (Table 1) (Poudel *et al*., 2020).

**Table 1.** Mean of grain yield and days to maturity of several wheat genotypes under heat stress.

| S.N. | Genotype | Grain yield in heat stress | Days to maturity |
|---|---|---|---|
| 1 | NL_1326 | 2173.25 | 97 |
| 2 | NL_1244 | 1455.25 | 99.75 |
| 3 | NL_1202 | 1277 | 100.5 |
| 4 | BHRIKUTI | 2152.5 | 99.25 |
| 5 | RR_21 | 1720 | 100.25 |
| 6 | NL_1327 | 1641.5 | 100.5 |
| 7 | GAUTAM | 1796.75 | 99.5 |
| 8 | NL_1307 | 1185 | 100.5 |
| 9 | BL_4708 | 2110.5 | 97 |
| 10 | BL_4699 | 2226.25 | 98.25 |
| 11 | NL_1207 | 1277 | 100.5 |
| 12 | NL_1211 | 1714.5 | 100.25 |
| 13 | NL_1325 | 1830.25 | 99.25 |
| 14 | NL_1253 | 2038.75 | 99.5 |
| 15 | NL_1260 | 1805.25 | 97.5 |
| 16 | BL_4707 | 1813.25 | 99.75 |
| 17 | NL_1247 | 1798.25 | 99 |
| 18 | NL_1254 | 1274.75 | 100.25 |
| 19 | NL_1328 | 1707.5 | 100.5 |
| 20 | BL_4335 | 2147 | 97 |
| | MEAN | 1793.65 | 99.25 |

Source: Poudel *et al*. (2020).

## Conclusion

Wheat is an important cereal crop which is consumed by majority of the people in the world. However due to rising in temperature in present context of climate change, heat stress has become a severe limitation on wheat production. This article has focused on the effects on wheat induced by heat stress. Heat stress adversely affect the root growth, seed germination, pollination, photosynthesis, and grain formation. It affects activities of critical enzymes, carbohydrate metabolism and synthesis of protein in grains disturbing the physiological process as well as the normal development of grain. It is known to make the plant complete its vegetative phase and enter reproductive phase earlier. These effects ultimately lead to reduction in yield. Hence, understanding about these effects can help us to identify various technologies for minimizing such effects on plant productivity when crops are exposed to unfavorable growing condition. A combination of the classical and modern molecular genetics tools with proper agronomic management practices can be helpful to overcome several complexities of heat stress.

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