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Effect of high temperature stress on crop plants

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Abstract
The detrimental effect of high heat on plant development is expected to have a widespread negative impact on plant growth as a result of global warming. Climate change is posing an increased threat of climatological anomalies, such as elevated temperatures, which might result in a severe reduction of agricultural yield and global famine. High temperature is an important physical stress which restricts crop growth, metabolism, and yield throughout the world. Plant growth and development depend on the number of temperature-sensitive metabolic processes. The degree and duration of high temperatures, as well as the plant species, all influence plant responses to high temperatures. It has now become a major source of concern for agricultural producers. Adaptive, avoidance, and/or acclimatization strategies are found in plants to cope with extreme temperature. This article focuses on the impact of high temperature stress on crop plants.

Keywords: Germination, growth, heat stress, high temperature, oxidative stress, photosynthesis, yield

Introduction

There are a number of different abiotic stresses that impact plant development and productivity, as well as yield. These stresses are typically linked, either separately or in conjunction. Crop plants are vulnerable to abiotic stresses such as heat, cold, salt and drought. During plant development and reproduction, temperature fluctuations are normal. Even while this is a good factor for plant development and fruit set, but excessive fluctuations during hot summers might disrupt the intermolecular connections essential for proper development. As a result of the rising threat of climate change, heat waves have a significant influence on agricultural productivity globally, putting future global food security in jeopardy (Christensen *et al.*, 2007) [6]. The continuous rise in ambient temperature is regarded as one of the most damaging stresses in the ever changing climate. The worldwide temperature is expected to climb by 0.2 °C every year, according to the United Nations. Temperature stress has a significant impact on plant growth and development since plants are sessile creatures that cannot migrate to more favorable conditions (Lobell, & Field, 2007) [22]. There are a variety of ways that high temperature can affect plant growth, development, physiology and harvest (Hasanuzzaman *et al.*, 2013) [14, 15]. Extreme temperatures can lead to generation of an excess of reactive oxygen species, leading to oxidative stress (Hasanuzzaman *et al.*, 2012) [13]. Environmental stress, such as high temperatures, forces plants to struggle for their survival. Plants are able to endure heat stress to a certain extent by undergoing physical changes inside the plant's body and by sending signals to its metabolism to adapt. Temperature-induced metabolic alterations include the production of biocompatible solutes that can assemble proteins and cellular structures, sustain cell turgor by osmotic adjustment, and modulate the antioxidant system to re-establish cellular equilibrium (Munns & Tester, 2008; Valliyodan & Nguyen, 2006) [27, 35].
Changes in gene expression under high-temperature circumstances lead to acclimatization, or in the best case, adaption, through altering physiological and biochemical processes (Hasanuzzaman *et al.*, 2010) [12]. It is a pretty big issue for plant researchers to produce novel crop cultivars that are resistant to high temperatures (Zhang *et al.*, 2006) [41].

Crop plants and high temperature stress

Temperature, duration, and plant type all influence plant responses to high temperatures. There are several ways high temperature affects plants. It affects every aspect of crop plant such as seedling germination, growth, development, photosynthesis, respiration, harvest.

Germination
Germination is a crucial developmental phase shift in the life cycle of plants that helps seedlings establishing and adaptation (Donohue, 2010) [9]. The life cycle of a plant commences with seed germination. Seed dormancy and germination are intricately linked and controlled by phytohormones (Hilhorst, 2007) [16]. Rising temperatures had a substantial detrimental impact on seed germination potential, resulting in lower seed viability and suboptimal germination. Germination is the first step of plant development to be impacted. Increased temperature has a detrimental influence on a variety of crops during seed germination, however the temperature ranges vary greatly depending on the plant types (Kumar *et al*., 2011) [20]. High temperature has been shown to lower germination rate, aberrant seedlings, inadequate seedling vigor, and diminished radicle and plumule development of geminated seedlings in several agricultural crops (Toh *et al*., 2008) [34]. Germination in *Triticum aestivum* was severely inhibited at high temperatures, which resulted in cell death thus lowering seedling establishment rates (Cheng *et al*., 2009) [5].

Growth
Heat stress has a detrimental impact on growth of many crop plants (Hasanuzzaman *et al*., 2013) [14, 15]. In reaction to high temperatures, plant height, no. of tillers, and biomass were lowered in a rice plants (Mitra & Bhatia, 2008) [24]. Increased temperature induces a loss of cell moisture content, resulting in a reduction in cell size and, eventually, growth (Rodriguez *et al*., 2005) [29].
Heat stress causes burning and sunburns on leaves, branches, and stems, leaf senescence, abscission, shoot and root development inhibition, and fruit discoloration (Rodriguez *et al*., 2005) [29]. Under high temperatures, leaf area and the number of tillers per plant were significantly reduced in *Triticum aestivum* (Djanaguiraman *et al*., 2010) [8]. As a result of denaturation of proteins, plants under high heat stress might display programmed cell death in certain cells or tissues (Rodriguez *et al*., 2005) [29].

Photosynthesis
Among plants' physiological activities, photosynthesis is one of the most susceptible to heat stress (Crafts-Brandner & Salvucci, 2002) [7]. Heat has a bigger impact on the photosynthetic capability of plants than low temperatures (Yang *et al*., 2006) [38]. Heat-induced chloroplast damage is thought to be caused by the stromal carbon metabolism and the thylakoid lamellae photochemical processes (Marchand *et al*., 2005) [23]. Extreme heat damages the thylakoid membrane. Under heat stress, chloroplasts undergo major changes, such as altered thylakoid structural organisation, impaired grana stacking, and enlargement of grana (Rodriguez *et al*., 2005) [29]. When leaves are under heat stress, their hydration status, stomatal conductance, and the amount of intercellular CO_2, they contain are all affected (Greer & Weedon, 2012) [10].
Another explanation for reduced photosynthesis is stomata closing due to high temperatures (Ashraf & Hafeez, 2004) [4]. Sorghum plants under heat stress shows a decrease in chlorophyll pigment owing to lipid peroxidation of chloroplast and thylakoid membranes (Mohammed & Tarpley, 2010) [25, 26]. A study by Kepova *et al*. (2005) [6] found that the average photosynthetic rates of *Vitis vinifera* leaves reduced as the temperature increased. The decreased amount of soluble proteins, rubisco binding proteins, large-subunits of rubisco, and small-subunits of rubisco are considered to be some of the additional factors that impede photosynthesis during heat stress (Sumesh *et al*., 2008) [32]. A plant's photosynthesis is negatively impacted by heat because it reduces the leaf's water potential, leaf area and the leaf's senescence occurs prematurely (Young *et al*., 2004) [39].

Respiration
Relatively little is known about the impact of extreme temperature stress on respiration (Al-Khatib & Paulsen, 1999) [1]. Increased temperature raises the cost of respiration to the point that photosynthesis can no longer compensate for respiratory losses, causing carbon shortage (Levitt, 1980) [21]. Depending on the organ's age, agricultural plants' respiration responses to high temperatures differ. As the temperature rises, the rate of respiration grows exponentially until it reaches its maximum at 45 °C, and then it declines with further increase in temperature (Almeselmani *et al*., 2009) [2].

Oxidative Stress
Enzymes that are vulnerable to varying degrees of high temperature are used in diverse metabolic processes. Heat stress, like other abiotic stresses, has been proposed to untangle enzymes and metabolic pathways, resulting in the buildup of undesired and damaging ROS, such as hydroxyl radical, singlet oxygen, hydrogen peroxide and superoxide radical which induce oxidative stress (Asada, 2006) [3]. The PSI and PSII reaction centres in chloroplasts are the primary sources of reactive oxygen species production, however reactive oxygen species is also produced in other organelles such as peroxisomes and mitochondria (Soliman *et al*., 2011) [31]. If photon energy is absorbed by PSI and PSII under such stress circumstances, the surplus of which is necessary for CO_2 assimilation is termed extra electrons, which lead to the generation of reactive oxygen species (Halliwell, 2006).
Plants suffer a variety of physiological impairments as a result of various amounts of temperature stress stress (Halliwell, 2006). Hydroxyl radicals have the ability to react with all biomolecules, including lipids, proteins, DNA and pigments, as well as nearly all cellular components. Protein, lipids and DNA may all be directly oxidised by singlet oxygen (Huang & Xu, 2008) [17]. Through the peroxidation of membrane lipids and protein denaturation, high temperature stress can lead to oxidative stress (Rodriguez *et al*., 2005) [29]. Because of the high temperature, anti-oxidant enzyme activities were decreased, which raised malondialdehyde concentration in rice plant leaves (Hurkman *et al*., 2009) [18]. Cell viability was significantly decreased in wheat as a result of heat stress-induced oxidative stress, which damaged membrane characteristics and caused protein degradation and enzyme deactivation. Furthermore, heat stress enhanced the membrane's peroxidation and decreased its oxidative stability, which led to an unexpected rise in the amount of electrolyte leakage from the cell membrane in wheat plants (Savicka & Skute, 2010) [30]. In spite of the fact that reactive oxygen species have a negative impact on plant metabolism, they are also thought to have signalling properties that activate heat shock responses in plants, which remain unexplained and should be unveiled (Asada, 2006) [3].

Yield

Concerns about agricultural production and food security are being raised due to rising temperatures. As a consequence, even a slight rise in temperature has a detrimental impact on crop production (Warland *et al*., 2006) [37]. Rising temperatures have a negative impact on grain yield mostly because they alter phenological development processes. Heated soils have been shown to reduce the production of numerous crops, including grains, pulses and oil-producing plants (Zhang *et al*., 2013; Warland *et al*., 2006) [40, 37]. It was shown that a one °C rise in the annual mean temperature significantly reduced cereal grain yields (Wang *et al*., 2012) [36].

Overnight high temperature increased spikelet sterility and lowered grain length, breadth and weight in rice plants (Suwa *et al*., 2010) [33]. Sorghum yield was lowered as a result of reduced seed weight and seed size caused by heat stress (Mohammed & Tarpley, 2010) [25, 26]. Assimilatory efficiency decreases as a result of lower photosynthesis owing to altered membrane stability, and maintenance of respiration costs increased during heat stress (Zhang *et al*., 2006; Reynolds *et al*., 2007) [40, 28]. Increased temperature also affects crop performance and quality. When *Hordeum vulgare* plants were subjected to heat stress, its grain quality attributes were dramatically altered (Hasanuzzaman *et al*., 2013) [14, 15].

Conclusion and future perspective

One of the primary environmental variables affecting grain crop yield is high temperature stress. By interfering with numerous physiological, growth, and yield processes, heat stress reduces agricultural output. A steady rise in global temperature is considered to be caused by the current rate of production of greenhouse gases from various sources, which is causing global warming. It is therefore necessary to better understand plant reactions and adaptations to high temperatures, as well as the mechanisms that underlie the development of heat-tolerance in major agricultural crops. It has been researched extensively in past few years how plants respond to heat stress but a comprehensive knowledge of thermo-tolerance mechanisms is still far from being achieved. In addition, plant responses to high temperature vary among various species and developmental stages. Food grain crops' resistance to high temperatures must be improved if yields and food security are to be improved. Breeding for high thermal tolerance is important not just in today's climates, but also in future climates that are predicted to have more high heat stress occurrences. It's time to look for new sources of high temperature tolerance. Many germplasm collections lack wild relatives of agricultural crops that may contain the greatest amount of temperature tolerance genes. As a result, wild genetic resources can give unique chances for the introduction or cloning and transformation of key genes from wild to cultivated crops, using both conventional and current approaches, in order to enhance crops. There is a dearth of material in our collections that prevents the utilization of wild relatives.

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