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Impact of Environmental Stressors and Agronomic Practices on Growth, Yield, and Chemical Composition of Chili Pepper (Capsicum Spp.): A Comprehensive Review

Opinion Article

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Abstract

Chili pepper (Capsicum annuum) is major crop in the global food supply and economies. However, the production of these crops is increasingly threatened by environmental issues such as water scarcity, soil salinization, fluctuating temperatures, and uneven fertilizer application. Such problems can hinder plant growth, production level, and quality. This review examines the impact of key environmental challenges on chili pepper, focusing on major compounds such as capacious, which impart pungency, as well as sugar, glutamic acid, and other markers of taste and nutrition. The review further discusses evidence from several other studies showing how these environmental parameters affect crop growth, biochemistry, and yield. In delineating the mechanisms through which these impacts are exerted, the review points the course for future research, which could develop strategies to make the crops more resilient in producing good quality, high-yield crops worldwide in the face of ever-increasing climate-related adversities.

Keywords: Chili Pepper; Environmental Stress; Water Supply; Salinity Stress; Temperature Stress, Fertilizer stress; capsaicin; Growth; Yield

Background

Chili pepper (Capsicum spp.) is one of the most important vegetable crops around the world. Fresh chili pepper is produced in 126 countries around the world, and around 55% of the world's chili production comes from South Asia, making it the region with the highest concentration [1]. The primary bioactive ingredient in chili that gives it its strong flavor and numerous health advantages is capsaicin [2]. Due to their high nutritional content, including a fair range of vitamins, minerals, phytochemicals, and dietary fiber, chili peppers are consumed worldwide and may help alleviate micronutrient deficiencies in humans [3].

The drought, high temperature, and heavy metal contamination are factors that can affect chili pepper growth. Most plant issues are caused directly and indirectly. For instance, harsh conditions can directly harm a plant, while stress makes it weaker and more susceptible to pests and diseases. When abiotic stress occurs alone or in combination, it significantly affects crop development and productivity. For instance, crop development, plant height, and leaf area all decline during drought stress, while cold stress lowers crop efficiency and plant growth, which lowers productivity [4]. According to [5], the main challenges to sustaining and enhancing vegetable yield will be rising temperatures, decreased irrigation water supply, flooding, and salinity.

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This review expresses the findings from different studies to explore how factors like water supply, salinity, temperature, and phosphorus fertilization affect the growth, yield, and chemical composition of chili peppers and tomatoes. By examining how these environmental conditions interact with plant metabolism, the review offers valuable insights into practical strategies for farmers looking to optimize crop production even in stressful situations.

Effect of Water Stress on Chili Pepper and Tomato Cultivation

Water stress directly affects and controls physiological processes, which determine the quality and quantity of plant growth [6]. In the early growth stage, water stress can cause a reduction in seed germination rate, and in the early vegetative growth stages, plants can show stunted growth and reduced root development. According to [7], plant height, number of leaves, fruit parameters, and yield parameters were significantly decreased in Japanese chili pepper when the plant was in the drought stress condition.

Furthermore, it significantly affects taste components in the fruits, including total sugar content, glutamic acid content, Brix, and capsaicinoid content in the placental septum of the chili pepper fruits [8]. This was again revealed by the finding of [9], when the plant was in a drought stress condition, capsaicinoid content in the placental septum was increased by accelerating capsaicinoid pathway genes.

Effect of Salinity Stress on Chili Pepper and Tomato Cultivation

Most of the plant varieties in the world are highly sensitive to high salinity levels in the soil. Salinity stress conditions can affect seed germination in chili pepper by reducing germination by reducing water availability and making it a harder environment for water absorption. Also, it may cause a delay or failure in sprouting. After germination, when the chili pepper plant is exposed to salinity stress conditions, it causes osmotic stress and makes the environment harder for nutrient uptake, and finally, it causes stunted growth. According to [7,10], plant growth parameters, fruit parameters, and yield parameters were significantly decreased in Japanese chili pepper when the plant was in the salinity stress condition. However, salinity stress significantly induced the increase of taste components in the fruits, including total sugar content, glutamic acid content, Brix and capsaicinoid content in the placental septum of the chili pepper fruits [11].

Temperature Stress and Its Impact on Chili Pepper and Tomato Cultivation

Heat stress is defined as an unexpected rise in temperature, typically 10 to 15°C cover ambient (Wahid et al., 2007). Extreme temperatures will reduce a plant's capacity to bear fruit since they will interfere with the pollination process [12]. Temperature stress can affect the quality of chili pepper by changing how it grows, its chemical makeup, and even its appearance.

This would be proven by [13], following ten hours of exposure, the temperature threshold of 32.86°C decreased chili plant yield by 50% when compared to the control by concluding the number of flowers, fruit set percentage, harvested fruit number, fruit weight, length, diameter, seed amount, and chlorophyll content all decreased under high-temperature stress, while flower abortion and damage to photosynthetic organelles increased. According to [14,15], plant growth parameters and fruit parameters with yield were significantly affected when the plant was in a higher temperature stress condition. Interestingly, the chili pepper plant produces higher capsaicinoid content under higher temperature stress [16].

Fertilizer Stress and Its Role in Crop Quality and The Development

Fertilizer stress may greatly affect the growth and yield components of chili pepper due to excess, insufficient fertilization, or imbalanced fertilizer application. Excessive fertilizer may affect plant growth and waste resources and contribute to environmental pollution, while insufficient fertilizer applications cannot meet the plant's basic soil requirements [17]. When the plants grow with phosphorus deficiency, they start to develop these special root structures called cluster roots, which have a lot of root hairs. This can also cause them to delay flowering and producing fruit [18]. According to a study by [19], adding phosphorus boosted the chili plants in several ways by improving plant height, increasing leaf area, and adding dry matter in both the shoots and roots, with higher fruit numbers, length, and moisture content. The availability of phosphorus can affect how chili pepper develops, particularly when it comes to the production of capsaicinoids. According to [14], the increment of phosphorus fertilization has negatively affected plant growth parameters and fruit parameters, with yield, while reducing its pungency level [20].

Conclusion

In summary, this review provides an overview of the complex relationships between environmental stress factors, crop management strategies, and the growth and yield of peppers and tomatoes. The results highlight the significantly adverse effects of abiotic stresses on plant biochemistry, nutrient uptake, and productivity. Therefore, to support the sustainable production of chili and tomatoes, better farming practices should be applied, and research initiatives to alleviate these impacts should continue.

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