

CLIMATE CHANGE IMPACTS ON VEGETABLE CROPS

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Vegetables crops are crucial for human diets as they provide essential nutrients, vitamins, minerals, antioxidants, and dietary fibres. Globally, more than 1.1 billion tons of vegetables are produced annually (FAO, 2023), with Asia contributing nearly 70% of this share. Also, they are source of livelihood for millions of farmers worldwide. However, the looming threat of climate change poses unprecedented challenges to vegetable production systems, directly affecting both yield and quality. The global climate is undergoing rapid shifts, characterized by rising temperatures, erratic rainfall, prolonged droughts, and increased frequency of extreme weather events such as floods, drought, cyclones, and heat waves. These changes disrupt the growth and development of the crops because vegetable crops require specific optimum temperature ranges for growth and reproduction.

Climatic factors that affect the vegetable crops productivity

Temperature: Most vegetable crops, including tomato, cauliflower, cabbage, and onion, have optimum temperature ranges. In Tomato, optimum fruit set occurs between 20-25°C. Temperatures above 35 °C induces flower bud drop and pollen sterility (Sato et al., 2000). In case of cauliflower when temperature is above >25 °C cause buttoning and curd loosening, significantly reducing market quality (Chakraborty & Newton, 2011). High night temperatures delay bulb initiation and reduce dry matter accumulation in onion which affects storability (Singh et al., 2019).

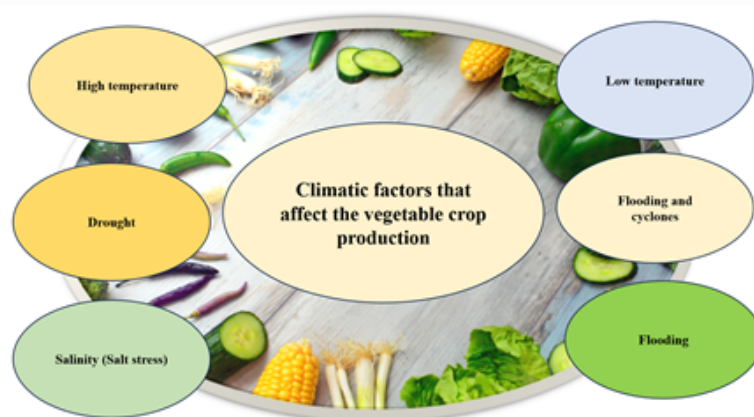


Low-temperature stress can be induced by either chilling (<20 °C) or freezing (<0 °C), both of which have differential effects on vegetables. In addition, freezing or chilling temperatures cause hindrance to seed germination as few seeds irregularly germinate, whereas others, for example, beans, do not.

Drought and Salinity: Irregular rainfall and salinity (salt stress) are major threats in vegetable crops. Vegetables such as okra and cucurbits reported yield reductions of 30-50% under moderate water stress (Kumar et al., 2018). On the other hand, excessive rainfall leads to waterlogging, reducing soil oxygen availability, which induces root rot in beans and wilting in solanaceous crops. Salt stress is inflicted on sensitive plants by means of water deficiency, the initial altered concentration ratio of K^+/Na^+ ions which reciprocated wilting, leaf abscission, respiratory changes, epinasty and leaf curling, turgor loss, reduced photosynthesis, a decline in growth, cellular integrity loss, necrosis, potential plant death, retarded plant development, poor seed germination, reduction in nodule formation, and poor crop yield.

Extreme events: Flooding and cyclones not only damage standing crops but also spread soil-borne diseases and pests. For instance, root rot in beans and downy mildew in cucurbits intensify under humid, waterlogged conditions. Floods undoubtedly create excessive moisture in the environment, thereby clogging the root zone and further affecting oxygen availability for aerobic processes. Tomato, for example, induces the excessive synthesis and accumulation of the ethylene precursor, 1-aminocyclopropane-1-carboxylic acid (ACC), as a result of lower oxygen levels under flooding conditions (Bhardwaj 2012).

Pest and Disease Dynamics: Shifts in temperature and humidity alter the life cycles of insect pests and pathogens. Warmer winters allow overwintering of pests such as whiteflies and thrips, which transmit devastating viruses. Similarly, fungal and bacterial infections thrive under changing rainfall patterns. This leads to higher pesticide dependency, raising concerns of resistance, residue, and environmental impact.



Adaptation and Mitigation Strategies Conclusion

To safeguard vegetable production in a changing climate, multi-dimensional strategies are required:

- **Breeding Climate-Resilient Varieties:** Development of heat-tolerant, drought-resistant, and disease-resistant hybrids through conventional and modern tools such as CRISPR gene editing.
- **Protected Cultivation:** Greenhouses, net houses, and low tunnels help regulate temperature and humidity, ensuring off-season production.
- **Water-Smart Practices:** Drip irrigation, mulching, and rainwater harvesting can mitigate water stress.
- **Integrated Pest Management (IPM):** Biological control, resistant varieties, and cultural practices can reduce reliance on chemicals.
- **Diversification and Crop Rotation:** Inclusion of short-duration and stress-tolerant vegetables reduces risks of complete crop failure.

The dual challenge of feeding a growing population and adapting to climate change necessitates urgent action in vegetable research and farming practices. Policymakers, scientists, and farmers must work hand in hand to promote climate-resilient agriculture. Cultivating advanced cropping practices like the use of shelters, raised beds, and mulching can help protect against flooding and high temperatures, and grafting techniques can eliminate the susceptibility of vegetable crops to soil-borne diseases, which enables the development of resistant crops. Harnessing genome sequencing of numerous vegetable crops can help identify genes having the capability to confer stress-tolerant and stress-responsive phenotypes, in addition to using new farm techniques like resource conserving technologies (RCTs) and modified crop and pest management practices. However, most importantly, educating farmers regarding indigenous practices and imparting technical knowledge along with spreading awareness about the serious threats posed to the farming communities and global food security by disastrous climate change can unite people from every social level toward developing immediate measures and utilizing the available resources most beneficially, thereby favouring vegetable production even under the most undesirable climatic conditions.