AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 02, Issue: 04 (April, 2025)
Available online at http://www.agrimagazine.in

Abiotic Stress Management in Fruit Crops under Protected Cultivation

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Abiotic stresses including high temperature, low temperature, drought, salinity, and nutrient imbalances are key limiting factors in the production of fruit crops globally. Protected cultivation provides a useful method to reduce these stresses by altering the microclimate surrounding plants. Yet even under controlled conditions, some abiotic issues remain. This article synthesizes techniques for controlling abiotic stress in fruit crops produced under protected structures such as greenhouses, polyhouses, shade nets, and high tunnels.

Introduction

Fruit crops are extremely sensitive to the environment surrounding them, and even minimal deviations from ideal conditions will adversely affect their reproductive and physiological development. Some of abiotic stresses like high temperature, chilling injury, drought, salinity, and nutrient imbalance are among the key factors that limit the productivity of fruit crops globally. These stresses not only constrain the vegetative growth & total yield but also affect crucial fruit quality parameters such as size, shape, flavor, color, firmness, and post-harvest shelf life (Boyer, 1982). Protected cultivation is revolutionary technology that provides a partial remedy to these issues by providing a controlled atmosphere for crop growth. These structures include greenhouses, polyhouses, shade nets, & high tunnels, which shield plants from outer climatic extremes and thus enable growers to produce high-value fruit crops year-round. The advantages consist of longer growing seasons, higher fruit quality, enhanced resource use efficiency, & greater economic returns (Sharma and Rao, 2013).

Even with these benefits, one must acknowledge the fact that protected structures cannot totally eradicate abiotic stress factors. On the contrary, they can create new problems if not properly controlled. Overheating during hot sunny days, poor ventilation causing high humidity and disease development, poor penetration of light during cloudy weather, and salinity accumulation due to fertigation are typical problems experienced under protected cultivation. In addition, night temperature drops, particularly in winter, can also induce chilling injury to susceptible fruit crops.Therefore, productive fruiting under protected cultivation requires a thorough insight into the relationship between plants and their altered environments. It also requires the application of an integrated abiotic stress management strategy involving microclimate control, effective water and nutrient management, employment of suitable varieties, and adoption of stress-reducing technologies. Management of these factors is imperative to realize the full potential of protected cultivation systems for profitable and sustainable production of fruit crops. We are revising the principal abiotic stresses faced under protected cultivation in this article and presenting innovative management practices and strategies to counter their negative effects on fruit crops.

Major Abiotic Stresses under Protected Cultivation

Protected cultivation greatly alters the environment of fruit crops, yet some abiotic stresses remain very challenging. The major abiotic stresses faced under protected cultivation are as given below:

1. Temperature Extremes: High temperature stress often occurs during the summer months due to insufficient ventilation in greenhouses or polyhouses. Excessive heat accumulation can lead to reduced fruit set, poor fruit quality, and in severe cases, plant mortality. Conversely, low temperature stress can impact fruit crops during winter nights, particularly in poorly insulated structures. Chilling injury, slowed growth, and delayed fruit development are common consequences of exposure to suboptimal low temperatures.

2. Water Stress: Both water deficiency and waterlogging may happen under protected cultivation if irrigation management is not well regulated. Drought stress, which affects photosynthesis and fruit growth, results from insufficient water supply, while root zone anoxia due to excessive irrigation or inadequate drainage systems leads to susceptibility of crops to fungal diseases and physiological disorders.

3. Salinity Stress: Salinity stress is a common problem under protected environments, primarily caused by the overapplication of fertilizers in conjunction with low-quality irrigation water. Constant fertigation in the absence of adequate leaching can result in salt buildup in the root area, which will lead to osmotic stress, nutrient disorder, and general loss of plant health.

4. Light Stress: Light intensity control is important under protected cultivation. Low light, caused by too much shading or overcast conditions, and high light intensity, leading to photoinhibition, can negatively impact plant growth. Low light diminishes photosynthetic efficiency, whereas too much light may result in leaf scorching and sunburn on fruit.

5. Nutrient Imbalance: Nutrient imbalance is also a common occurrence under protected cultivation due to excessive dependency on fertigation systems without periodic soil or substrate analysis. Nutrient deficiencies and toxicities may result, which can lead to physiological disorders like blossom end rot in tomato or tip burn in leafy vegetables, ultimately lowering fruit yield and marketability.

Management Strategies

A balance of structural, agronomic, and technological controls is needed in managing abiotic stresses under protected cultivation. Effective strategies include the following:

1. Microclimate Regulation: There is a critical need for regulating microclimates within protected houses to reduce temperature and humidity-induced stresses. The use of ventilation systems such as side vents, ridge vents, and exhaust fans facilitates effective exchange of air and minimizes heat buildup (Kittas et al., 2012). The thermal screens being retractable enable trapping of heat at night to save plants from cold stress and deflecting solar radiation during the day to avoid heat stress. Moreover, the use of fogging and misting systems raises humidity levels and reduces the ambient temperature, which is especially useful for crops such as strawberry and capsicum during peak temperatures.

2. Effective Irrigation and Drainage: The use of drip irrigation systems enables accurate and uniform application of water and therefore evades both water scarcity and waterlogging. The use of soil moisture sensors helps the farmers maintain optimal levels of moisture in the soil by offering real-time information, hence avoiding the development of drought or flooding stress in the root zone.

3. Soil and Water Management: Employment of inert growing media like cocopeat, perlite, and rockwool in place of conventional soil culture reduces salt accumulation and enhances root aeration. Testing of water quality for irrigation frequently is essential for the identification of salinity risks in the early stages, allowing for corrective action through water treatment or choice of salt-resistant rootstocks.

4. Shading and Reflective Mulching : The application of shade nets, usually with 30–50% shading intensity, during hot summer seasons decreases solar radiation, thus safeguarding crops from heat stress. Reflective mulches, especially aluminum-coated plastic films, are efficient in promoting light diffusion, lowering soil temperature, and improving fruit quality by preventing direct heat stress on developing fruits.

5. Crop Selection and Varietal Improvement: Choosing fruit crop varieties that are naturally tolerant to heat, drought, or salinity increases the resistance of production systems under protected cultivation. In addition, the method of grafting sensitive scions onto stress-tolerant rootstocks, like grafting watermelon on bottle gourd rootstock, offers an efficient biological solution to counter soil-borne stresses like salinity and drought.

6. Application of Antitranspirants and Growth Regulators: The use of antitranspirants like kaolin clay, chitosan, or abscisic acid (ABA) sprays can suppress transpiration loss in hot temperatures, thereby saving water status of plants. The application of plant growth regulators such as cytokinins through leaf application can inhibit senescence and increase tolerance of stress at the time of water deficit.

7. Integrated Nutrient Management: An integrated nutrient management strategy, rooted in regular soil and foliar nutrient analysis, provides balanced fertilization in coordination with the crop growth stage and nutrient requirements. Tailoring fertigation schedules in relation to the actual crop requirements prevents nutrient deficiency and toxicity, which are typically the causative agents of physiological disorders in covered conditions.

Case Studies

Protected cultivation practices, when well-executed, have proven to produce real benefits in different fruit crops. For example, under polyhouse production of strawberries, the provision of misting systems has been effective in lessening heat stress by as much as 20% and improving fruit set by a similar percentage (Singh et al., 2020). Grape production in net house conditions has also received a boost with enhanced ventilation as well as reflective mulches that have led to reduced sunburn damage and higher berry size and quality (Patil and Kadam, 2017).

Conclusion

Protected cultivation presents enormous opportunities to increase the quality and productivity of fruit crops through the alleviation of abiotic stresses. Nonetheless, these buildings are not fully exempt from adversity and can become sources of fresh environmental stress in their own right if they are not managed adequately. Thus, an integrated strategy including structural alterations, microclimate management, effective water and nutrient management, judicious crop selection, and the incorporation of state-of-the-art technologies is necessary for ensuring sustainable and remunerative production of fruits under protected cultivation systems. An active and well-informed management approach will not only protect the crops from abiotic stresses, but will also enhance the resource use efficiency and economic sustainability of protected horticulture.

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