Climate Change Impact on Horticultural Crops: A Review

Abstract

Our civilization is fundamentally based on agriculture, which provides resources and food to an expanding population. But because of rising temperatures, altered rainfall patterns, and a rise in the frequency and severity of extreme weather events, climate change is endangering this industry. Our study aims to fill a significant gap in the existing literature by focusing on the effects of climate change on vegetable crops. It also highlights the need to address climate change in a differentiated manner, taking into account the unique characteristics of each agricultural sector. By using the Web of Science and Scopus databases, 219 publications were carefully examined to see which ones fully addressed how climate change is affecting vegetable crops. Only 53 of the 219 publications that were reviewed were solely concerned with how climate change is affecting vegetable crops. This suggests that more specialised research is needed in this field, especially considering the complex issues that climate change raises regarding yield, non-trivial quality, and food safety. Future research in this area is therefore encouraged.Crop-based adaptation techniques are required, taking into account the crop's characteristics, degree of sensitivity, and agro-ecological zone. In addition, monitoring the ability of various horticulture crops to absorb carbon dioxide in comparison to annual field crops can help create a blueprint for addressing climate change-related problems.

Keywords:

Climate change, Horticultural crops, environmental factors; climatic disruptions; food security

Introduction

Regarding the worldwide and regional effects of anticipated climate change on agriculture, water resources, natural eco-systems, and food nutritional security, the Fourth Intergovernmental Panel on Climate Change (IPCC) report correctly imagined [9, 5]. Abiotic stressors like drought, hailstorms, heavy rain, floods, frost, cyclones, and other natural disasters affect different provinces and regions annually, and these events are attributed to climate change.

Due to increased rainfall unpredictability and high and low temperature regimes brought on by shifting weather patterns that are causing a change in climate, agricultural output is at risk [8, 7, 6].A key concern affecting the performance of agriculture, particularly horticultural crops, both annual and perennial, is climate change and its variability. Short growing seasons are likely to be the cause of the decline in fruit and vegetable production because they negatively affect growth and development, especially when it comes to terminal heat stress and reduced water availability. Variability in rainfall and fewer rainy days will be the main effects on rainfed agriculture [10].More dangers and uncertainties have been raised by the problem of climate change and variability, further increasinglimitations in systems of horticulture production. There could be an increase in the cost of fruits and vegetables due to climate change. The challenges that lie ahead include maintaining sustainability and competitiveness, as well as achieving the targeted production needed to meet the increasing demands in the face of diminishing land and water resources and the threat of climate change. To improve production in these challenging environments, climatesmart horticulture interventions are required, which require a high degree of location specificity and knowledge [11, 12].

Consequences for horticultural crops

The impact of new cultivars and production system management on technological advancements is evident in higher productivity and production, which increased by more than eleven times to 456.2 million tonnes in 2021–22(3rd estimates) from 25 million tonnes in 1950–51 [12]. The horticulture industry has undoubtedly advanced despite numerous obstacles and flaws, and it is currently at a critical stage of growth that calls for measures for sustainable development. Vertical growth through the use of new cultivars, effective water and nutrient management, effective plant health management coupled with strategies for reduced post-harvest losses could be the approach, which would require appropriate innovation and investment, to achieve the targeted production of 310 million tonnes of horticultural crops by the end of the XII Plan (2012–17) [4, 3]. The challenges and effects of climate change, such as altered seasonal patterns, excessive rain, flooding, hailstorms, frost, high temperatures, and drought that causes extremes, must be addressed in order to achieve increased horticultural production. Reduced water availability, shorter growing seasons, and inadequate vernalization can all result in lower yields.

We require comprehensive data on the physiological reactions of the crops, effects on growth and development, quality, and production in order to measure the effects of climate change on horticulture crop [1]. To get ready for the impending difficulties of climate change, the horticulture sector needs to handle the diverse implications in a coordinated and methodical manner. Increased respiration, altered photosynthetic rate, and partitioning of photosynthates into economically significant portions are all caused by temperature increases. Along with modifying phenology, it may also shorten crop duration, flowering and fruiting days, and accelerate fruit maturity, ripening, and senescence [2]. A crop's sensitivity to temperature varies depending on its growing patterns and innate tolerance. Because indeterminate crops flower later than determinate crops, they are less susceptible to heat stress situations. The increase in temperature might not be spread equally during the day and night and throughout the seasons [13]. In tropical areas, yield declines may be excessive even in the case of modest warming. A slight rise in temperature can lead to an improvement in crop production in high latitudes. Since most emerging nations are found in lower latitudes, where temperatures are already close to or above thresholds, additional warming will decrease rather than boost productivity. The effects of climate change are likely to vary depending on the crop type and locality; these effects are discussed here for many horticultural crop subsectors.

Fruit trees

It has been noted that many fruit crops suffer significant damage from hot and cold wave conditions, which are extreme weather phenomena. Temperature is said to affect flowering in perennial crops like guava and mango.

Mangos have a vegetative bias that affects the phenology of flowering and gets greater with temperature. Higher temperatures were correlated with a higher percentage of hermaphrodite flowers in late emerging panicles [14, 15]. Peak bloom period temperatures of 35ºC combined with long sunny hours, low relative humidity of 49%, and heavy transpiration caused panicles to get dehydrated and suffer damage.

Mango trees, both bearing and non-bearing, frequently experience leaf scorching and twig death as a result of heat stroke. Early or delayed flowering, repeated reproductive flushes, differences in fruit maturity, irregular fruit set, and the conversion of reproductive buds into vegetative ones are some of the major consequences of climate change on mangos that have been reported [16]. The BiologischeBundesanstaltBundessorttenamt und ChemischeIndustrie 13 (BBCH) scale for phonological research in mangos has been modified for the purpose of monitoring climate change [17]. The hot, humid weather has led to a significant rise in pests and diseases in guava. Because of the heat and humidity, fruit flies in guava are getting more and more common. According to [18], crops like peaches and plums that require low chilling temperatures are also exhibiting signs of declining yield.

Furthermore contributing to sunburn and apple, apricot, and cherry cracking happens due to high temperatures and moisture stress. An increase in temperature at the time of fruit maturity causes premature mango ripening as well as fruit cracking and burning in litchi [19]. In citrus, untimely winter showers encourage vegetative flushes rather than flowering flushes. A dry spell that occurs during fruit set and flower emergence impacts the start of flowers and increases pest incidence (Psylla).

For many slow-growing fruit crops, planting orchards will need a significant financial outlay. Under the effects of climate change, quickly changing or shifting fruit species or kinds would be a tough and unpleasant exercise in suffering losses, which may inhibit development. According to recent studies, orchards in the Shimla area, which is at a somewhat higher altitude, have switched from high-chilling apple varieties like Royal Delicious to low-chilling cultivars and other fruit crops like kiwi, pear, peach, and plum as well as vegetables. The mid-hills of the Shimla district are seeing a complete change away from the cultivation of potatoes and apples. It is supported by the downward trend in Himachal Pradesh's apple productivity and snowfall. Apple output decreased to 5.8 tonnes/ha from 10.8 tonnes in 2001 [20]. Moving production locations is a challenge because many crops requiring chilling are tree species. Choosing varieties that require less freezing would therefore be wise for replanting orchards and plantations throughout the course of the following ten years. This is but one illustration of the soon-to-be effects of climate change and global warming.

Fruit growth is greatly influenced by temperature; hence, using bunch covers to warm the fruit has been shown to accelerate growth. In general, banana plants mature more quickly at temperatures between 31 and 32 degrees Celsius, which reduces the bunch development period [21]. Sunburn damage to exposed fruits is caused by higher air temperatures (over 38 °C) and stronger sunshine.

Drought and extreme temperatures (above 38 °C) can also cause bunch [22].Despite having originated in temperate regions, grapes have been able to adapt to tropical climates by adjustments to their production system, which involves two prunings and one crop.The availability of growing degree-days (GDD) and temperature will alter under climate change conditions, hastening the phenological processes [23, 24]. Vine plants cannot use radiant energy at temperatures above 42°C, presumably due to enzyme deterioration and a chlorophyll content that above that of photosynthesis [23]. The development of anthocyanins in wine grapes is impacted by the significant temperature differential (15–20 ºC) between day and night, which fosters the development of colour. Therefore, in such a situation, we would need to determine which types and locations are best for producing high-quality fruits. In general, grapes that are exposed to very high temperatures for prolonged periods of time experience delayed fruit maturation and decreased fruit quality.

Temperature tolerance varies throughout varieties [24]. Generally speaking, 28 days following temperature treatments, the ideal temperature for shoot and root growth was 20/15°C for Semillon, Cabernet Sauvignon, and Cynthiana, and 30/25°C for Pinot Noir and Chardonnay. Severe water stress in citrus reduces leaf initiation, reduces leaf size, and makes leaves leathery and thick. Water stress has a negative effect on root growth.In citrus, it might result in deeper rooting and a larger percentage of feeder roots. Water stress during development decreased the commencement of inflorescences in grapevines and also decreased shoot growth. Grape berries grow less while under water stress, although this has no effect on the typical double sigmoid growth curve. In general, berry size will be reduced more by a water deficit during stage I (cell division) than by a water deficit during stages II and III (growth cell expansion). Water stress greatly increased anthocyanin biosynthesis, and wines made from water-stressed plants had high anthocyanin concentrations that resulted in a more intense colour [28, 27, 26]. Water deficiency also positively enhanced polyphenol accumulation in berry skin. Water stress caused by a 34-day irrigation stoppage in papaya stunted plant development, caused leaf abscission, and significantly reduced photosynthetic rate. It follows that the impact of water stress is more dependent on the stage of growth; stress at the fruit's growth stage is harmful, whereas stress prior to blooming is necessary to achieve flowering. Smaller fingers, fewer bunches, and poor bunch formation are all results of soil water stress in bananas during the vegetative stage. Plant growth would be hampered by any water deficiency, and the consequences could not always become apparent for several months following the drought [29]. Water stress during flowering results in unmarketable bunches and inadequate finger filling. The bunch weight and other growth metrics decrease under water stress. High water use efficiency in a variety of horticulture crops has been made possible by microirrigation techniques [38].

According to studies done on apples, productivity will continue to drop up to 1500 m msl by 40–50% because of the warmer climate, which results in fewer chilling requirements in the winter and warmer summers at lower elevations. As a result, apple production will move to higher elevations (2700 m msl). Flowers are affected by winter snowfall. Warm temperatures cause the floral components to desiccate, while low, variable temperatures throughout the bloom lead to poor fruit set. In almond and apricot, mild winters and warmer springs accelerated bud burst and exposed buds to frost damage.Apples, apricots, and cherries were more susceptible to sunburn and cracking due to high temperatures and moisture stress [37].

Crops of spices and plantations

For abundant flowering, cashew needs a reasonably dry and warm winter (15–20°C minimum temperature) with moderate nighttime dew. The afternoon's high temperature (>34.4°C) and low relative humidity (<20%), which dry out the blossoms, reduce yield. According to [32], insufficient and uneven rainfall, elevated temperatures, and strong winds can cause cashew trees to produce fewer fruits, fallen leaves, and dried out flowers. In extreme cases, these factors can even cause the trees to become unproductive.

Unseasonal rains during the apple-ripening stage cause the apples on trees to rot and the nuts to become black. From January to May, cashew is severely stressed by moisture, which has a negative impact on flowering and fruit set. In situ soil and water conservation as well as rainwater harvesting are crucial for collecting rainwater and supplying it to the cashew plant during the critical phase [31]. The Godavari district of Andhra Pradesh experienced a 6 year reduction in crop production of 220 million nuts annually as a result of the 1996 cyclone [36]. Climate change is predicted to have a positive impact on coconut productivity in the western coastal regions of Kerala, parts of Tamil Nadu, Karnataka, and Maharashtra (assuming that the current level of water and management is made available in future climates as well). It is also predicted to have a negative impact on Andhra Pradesh, Orissa, West Bengal, Gujarat, and parts of Karnataka and Tamil Nadu. This assessment was made by Naresh Kumar and Agarwal in 2016. At several phases of the plant's life cycle, climate fluctuations have a significant impact on oil palm production. For example, if evapo-transpiration is decreased, leaf opening is delayed, and sexual differentiation is impacted. In the first and subsequent harvests, the final production will be lowered if any of these conditions are not satisfied. [34] and [35] reported that the impact of Hurricane Nina and flood-related issues in southern Malaysia had reduced crude palm oil production to 1.1 million metric tonnes (26.3%) in December 2006. Agroforestry systems based on cocoa are thought to store large amounts of carbon, which makes them potentially helpful in reducing the effects of climate change. According to [33]-[32], carbon stocks in shaded agroforestry systems with perennial crops like coffee (Coffea arabica L.), rubber [41, 40, 42], and cocoa may vary between 12 and 228 Mg/ha and may be able to mitigate climate change.

Vegetable-based crops

The monsoon, which provides surplus and limited water stress conditions and is primarily responsible for the majority of the region's precipitation, dominates the Indian climate. Due to their succulent nature, vegetables are typically sensitive to variations in temperature and moisture content. As a result, low yields are often caused by these factors. Early on in the establishment of onion crops, soil water stress resulted in a 26% production reduction. According to [46] water stress and temperatures above 28°C caused a 30-45% bloom decrease in various tomato varieties. Drought stress affects chillies as well, resulting in a 50–60% reduction in production. According to [44, 45] pre-anthesis temperature stress is linked to abnormalities in the anthers' development, specifically in the epidermis and endothesium, absence of stromium opening, and inadequate pollen production. The ideal daily mean temperature for tomato fruit set has been shown to be between 21 and 24°C. In tomatoes, the pre-anthesis stage is more delicate.

The majority of types are susceptible to higher temperatures and delayed curd commencement is noted, even if some have evolved to temperatures beyond 30°C [48]. Stresses related to heat and water are probably going to have the biggest impact on horticultural commodities' quality. According to [47], raising the temperature of onions beyond 40°C decreased their bulb size and raising the temperature above 38°C decreased their yield. High temperatures have been shown to diminish potato marketable grade tuber yield by 10–20%, and frost damage has been shown to reduce tuber output by 10–50%, depending on the severity and timing of the damage.

Through morphological or biochemical mechanisms, plants can adapt to escape one or more pressures [49,50].

Utilising location-specific, climate-smart horticulture to combat climate change

Climate-smart horticulture isn't a single, all-encompassing agricultural technique or technology. This strategy calls for site-specific evaluations to determine appropriate production techniques and technology to solve the various issues that agricultural and food systems face concurrently and comprehensively [51, 52]. Although there is global climate change, the type, scope, and intensity of the change vary depending on the area.Climate change concerns and their resulting difficulties therefore necessitate local planning, administration, and analysis. In order to provide practical answers to the issues, it is necessary to assess and comprehend how climate change is affecting both annual and perennial horticulture crops at the regional level [53]. This can be done through innovation, technological review, and refining.

Models of simulation for effect evaluation

Using modelling methods for impact analysis for different horticulture crops will be appropriate when developing adaptation and mitigation strategies. Except for potatoes and coconuts, horticulture crops (fruit and vegetables) lack suitable simulation models that are readily available or have been developed in India. The Info Crop model has been modified for use with tomato and onion crops, and it is currently undergoing validation for several agro-ecological zones (Naresh Kumar et al, 2008). Large fruit trees and bushes pose challenges in studying the direct effects of many factors on growth, development, and yield in controlled environments due to their perennial nature. Priority should be given to developing simulation models for significant horticulture crops such as mango, grape, apple, orange, citrus, litchi, guava, etc. Innovative methodologies are needed for this. Creating crop simulation models for India's horticultural crops is currently a top research focus.

Strategies for adaptation

The system's capacity for change adaptation is just as important as the climate itself for determining the possible effects of climate change. The potential is contingent upon the crops' ability to adjust to the simultaneous environmental challenges resulting from climate change. Crop-based adaptation methods that integrate all available choices to sustain productivity must be devised, taking into account the growing season and the susceptibility of each crop in an agro-ecological region.

Numerous solutions have already been developed by scientists to deal with extreme events such as high temperatures, frost, and stress conditions caused by both restricted and excessive moisture [61, 62]. Utilising and integrating these existing technology could help lessen the negative effects of climate unpredictability and change. To lessen the effects of climate change and boost the resilience of horticulture production systems, more focus needs to be placed on creating crop, agro-ecological region, and season-based technologies [59]. In order to counteract climate change, resistant root stocks and cultivars for different fruit crops that are tolerant of stressors have been identified.

Strategies for mitigation

There is ample evidence to support the fact of climate change, including the link between greenhouse gas emissions and global warming.The horticulture industry can significantly aid in mitigation of the negative effects of climate change in addition to modifying horticultural production systems to withstand their effects. The process of either reducing or sequestering greenhouse gas emissions is known as mitigation. Because of a decreased reliance on energy needs, improved crop management techniques can significantly reduce greenhouse gas emissions. Additionally, intensifying perennial horticultural crops can aid in the sequestration of carbon dioxide from the atmosphere.

Potential for sequestering carbon

As a potential source of extra income for rural communities that might otherwise struggle financially and as a way to support climate change adaptation, mitigation measures in the agriculture and forestry sectors are attracting a lot of attention. Carbon sequestration is one method of mitigation that helps lessen the negative effects of climate change. Despite their considerable contribution, little is known about fruit trees' capacity to sequester carbon. The mitigation potential of farm forestry fruit orchard block planting was assessed in a study conducted at IISC, Bangalore, using the PRO-COMAP model. Mangifera indica, Tamarindus indica, Achras sapota, Artocarpus, Neem, and Guava were proposed for 75% of the projected area. For the 30-year period (2005–2035), the carbon stock change under the baseline and mitigation scenario (apart from harvested wood products) and the carbon increment per ha for different project activities came out to be 47.42 tC/ha. With a 5,381 ha area, agricultural forestry has an overall mitigation potential of 81,750 tC. orchards of fruits The highest IRR of 29.92% is reported in agricultural forestry [57, 58].

Technological advancement to lessen impact

Actually, grapes are a temperate fruit that are typically grown in cool climates, whether they are being grown for wine or for use in tableware. However, technological advancements in plant architecture and production system management have made it possible to produce grapes in tropical climates with the highest global output. Similarly, the high temperatures in the mid-hill agroclimatic conditions may produce pollen desiccation and fruit shrivelling, which will limit yield and increase crop failure. The freezing will also not be sufficient to stimulate blooming in apples. These are the anticipated effects that give rise to the worries. However, there are countless examples that demonstrate how the climate has been changing and how technology has assisted in reducing the impact of these changes. Alkalinity and salinity posed significant challenges to the effective growth of grapes, but the discovery of appropriate rootstocks has greatly increased yields. Potatoes, tomatoes, cauliflower, and cabbage are examples of thermosensitive crops that were only productive during lengthy days in temperate climates. However, it is now possible to achieve extremely high productivity even in subtropical and mild subtropical climates as well as warmer ones because to the introduction of heat-tolerant cultivars and modifications in production system management [56, 54]. These historical experiences serve as a powerful reminder that, with creative investigation, the threat posed by climate change can be turned into an opportunity. However, this will require the visualisation of the shift's anticipated course, as well as preparation for its negative effects and strategies to lessen them. The biotechnology technologies that are already available could speed up the transmission of study findings.

Conclusion

These research' geographic distribution reveals a notable bias in favour of highly industrialised nations like the US, China, India, the UK, and Germany. This may be explained by the fact that science is funded and conducted more frequently in these nations, but it also draws attention to a major research vacuum in less developed or industrialised nations, where there may be less capacity for adaptation to climate change and therefore more severe effects.The literature now in publication, which spans disciplines from agronomy to environmental sciences, indicates an all-encompassing method for comprehending the practical and ecological facets of climate change impacts. Nonetheless, agricultural output continues to receive the majority of attention, with less emphasis being placed on other crucial elements like food safety, nutritional value, and pest and disease management.Just 53 of the 219 publications that were analysed had a sole emphasis on how climate change is affecting vegetable crops. Moreover, many of these have not received enough attention in terms of citations, despite the small number of relevant studies. This emphasises the need for additional expert research in this field, particularly in light of the intricate problems that climate change presents to yield, nutritional value, and food safety.

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