Effects of climate change and greenhouse gases emission relevance to environmental stress on horticultural crops

Abstract

The yield and quality of sustainable horticulture crops are significantly impacted by global climate change. The agricultural community has been forced by rising global temperatures to modify planting and harvesting timetables, which frequently calls for earlier crop production. Notably, a number of concerning elements are brought about by climate change, including greenhouse gas emissions (GHGs), higher temperatures, higher concentrations of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), ozone depletion (O_3), and deforestation. All of these factors exacerbate environmental stresses on crops. Climate change is therefore likely to have a negative impact on livestock production and crop yields. Thus, the main goal of the review paper is to provide a thorough summary of the various aspects that affect the production of fruits, vegetables, and plantation crops in horticulture, with a focus on greenhouse gas emissions and environmental stressors like high temperatures, droughts, salinity, and CO_2 emissions. This assessment will also look at how new greenhouse technologies and horticultural crop varieties can be used to lessen the negative effects of climate change on agricultural crops.

Keywords: Carbon trade, Carbon sink,; Climate change; Greenhouse; Horticultural crops.

Introduction

Climate change is defined as variations in the global temperature over a comparable length of time that are either directly or indirectly caused by human activities changing the composition of the atmosphere. Over the past century, the average global temperature of the earth's surface has risen by roughly 0.74°C. 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 (IPCC 2007) appropriately envisioned. Abiotic pressures like drought, hailstorms, heavy rain, floods, frost, cyclones, and other natural disasters affect different provinces and areas every year, and these events are attributed to the effects of climate change. A shifting climate due to altered weather patterns has put agricultural productivity at risk by high and low temperature regimes and increased rainfall variability (Malhotra and Srivastava 2014, Eduardo et al. 2013).

One of the main issues impacting the performance of agriculture, particularly horticultural crops, both annual and perennial, is climate change and its unpredictability. The short growing season, which will have a detrimental effect on growth and development especially because of terminal heat stress and lower water availability, is probably the cause of the reduction in fruit and vegetable yield. Rainfall variability and a decline in the number of rainy days would have the biggest effects on rainfed agriculture (Venkateswarlu and Shanker 2012). Horticultural production systems are now subject to additional constraints because to the uncertainties and dangers associated with climate change and variability. Fruit and vegetable crop prices may rise as a result of climate change. The challenges that lie ahead are those of sustainability and competitiveness, as well as achieving the targeted production 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, climate smart horticulture interventions are necessary, and they require a high degree of location specificity and knowledge (Malhotra and Srivastava 2014, Malhotra 2015).

In the troposphere, or lower atmosphere layer, where weather and life exist, the greenhouse effect takes place. The average surface temperature of the Earth is predicted to be approximately -19°C in the absence of the greenhouse effect, as opposed to the current average of 14°C (Le Treut et al., 2007). Greenhouse gasses (GHG) are what cause the greenhouse effect. According to the IPCC (2014), greenhouse gases (GHGs) are the gaseous components of the atmosphere that both emit and absorb thermal infrared radiation. The troposphere contains traces of both naturally occurring and man-made greenhouse gases. In ascending priority order, the most prevalent greenhouse gases are: water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxides (N_2O) and ozone (O3). GHG percentages vary daily, seasonally, and annually. The primary organic trace gas in the atmosphere is methane (CH4). The main component of natural gas, a fuel that is used all over the world, is CH4. Agriculture and cattle raising produce significant amounts of greenhouse gas emissions, primarily as a result of the use of fossil fuels. Since the pre-industrial era, CH4 concentrations have increased by a factor of two. As of 2014, the average concentration across the globe is 1.8 µmol.mol-1. Despite the fact that its concentration is just 0.5% of CO2, worries are raised about an increase in the atmospheric release of CH_4. As a greenhouse gas, it is in fact thirty times more potent than CO_2 (IPCC, 2014). In addition to producing O_3, CH_4 and CO_2 help regulate the amount of OH in the troposphere (Wuebbles and Hayhoe, 2002).

Impact of greenhouse gases on horticultural crops

Effects of increased CO2 Twenty percent of the heat absorption is caused by carbon dioxide (Schmidt et al., 2010). Respiration, seawater release, and organic decomposition are examples of natural sources of CO2. Anthropogenic sources of CO2 emissions include the production of cement, deforestation, and the burning of fossil fuels including coal, oil, and natural gas. Remarkably, industry accounts for 21% of direct CO_2 emissions and agriculture, forestry, and other land uses for 24% (IPCC, 2014). Over the last 200 years, atmospheric CO_2 concentrations have increased significantly, from approximately 270 µmol.mol-1 in 1750 to current levels of over 385 µmol.mol-1 (Mittler and Blum Wald, 2010; IPCC, 2014). Since the 1970s, around half of all anthropogenic CO_2 emissions between 1750 and 2010 have occurred (IPCC, 2014). According to calculations, the global mean surface temperature would rise by 3-5°C in 2100 as a result of rising CO_2 concentrations and positive feedback from water (IPCC, 2014).

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 283.2 million tonnes in 2015–16 (3rd estimates) from 25 million tonnes in 1950–51 (Malhotra 2016). The horticulture industry has undoubtedly advanced despite numerous obstacles and failings, and it is currently at a pivotal stage of growth that calls for initiatives for sustainable development. Vertical growth, through the use of new cultivars, efficient 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).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, as well as effects on growth and development, quality, and production, in order to effectively evaluate the effects of climate change on horticulture crops. To get ready for the impending difficulties of climate change, the horticulture industry must handle the diverse implications in a coordinated and methodical manner. Increased respiration, altered photosynthesis, and the partitioning of photosynthates into economically significant portions are all caused by temperature increases. Moreover, it can change the phenology, accelerate fruit maturity, ripening, and senescence, and decrease the crop's growing season and number of blooming and fruiting days. A crop's sensitivity to temperature varies depending on its growing patterns and innate tolerance. Because they flower later than determinate crops, indeterminate crops are less susceptible to heat stress. Seasons and day and night variations in the temperature rise may not be equally distributed (Srinivas Rao et al. 2010). In tropical areas, yield declines may be excessive even with mild warming. A slight rise in temperature can lead to an improvement in agricultural yields in high latitude regions. Since most emerging nations are found in lower latitudes, temperatures there are already near to or beyond thresholds, and more warming would decrease rather than boost production. 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.

Impact of NO_2

Over the past few decades, there has been an increase in the emission of atmospheric nitrogen dioxide (NO2) in various parts of the world (Munzi et al., 2009), particularly in some Asian nations (Hu et al., 2015). The NO2 concentration is expected to continue rising and above the standard limit of NO2 pollution due to the expansion of industrialized production and the ongoing rise in vehicle exhaust emissions (Hultengren et al., 2004). Ozone and particle matter are two dangerous secondary air pollutants that are preceded by nitrogen dioxide (NO2) (Rahmat et al., 2013, Brmejo-Orduna et al., 2014). It is crucial to employ ecological techniques, such as plant uptake and atmospheric NO2 catabolism, to lower air concentrations. Scholars now disagree on many aspects of NO2's effects on plants. One theory states that NO2 can generate organic nitrogenous molecules in plants by metabolization and incorporation into the nitrate absorption pathway. According to a different theory, most plants show resistance to NO2 in addition to low levels of NO2-N incorporation into total plant nitrogen (N) (Morikawa et al., 2001). When plants are exposed to NO2, complex physiological reactions can occur, such as modifications in the activity of antioxidant enzymes (Liu et al., 2015). N metabolic enzyme activity, as well as the makeup and arrangement of nitrogenous metabolic products in plant tissues (Vighi et al., 2017). Low amounts of NO2 can dissolve in water to generate nitrate and nitrite, which are then used by plants in the course of their regular nitrate metabolism. In this way, NO2 can function as an airborne fertilizer. On the other hand, distinct plant species react physiologically differently when exposed to NO2. As a result, there is ongoing debate on the effects of NO2 exposure on plants, and no consensus has been achieved. Furthermore, little is known about the various plants that naturally recover from high NO2 concentrations. We investigated the physiological reactions of 41 garden plants from Jiangsu Province that were subjected to various NO_2 environments under controlled laboratory circumstances in order to find plants that show robust resistance and good absorption. Few research have looked into whether these 41 plant species, which are frequently planted by roadsides in many nations' cities, have a high capacity to absorb NO_2 or are resistant to its effects. Numerous research works have examined how NO_2 concentration affects plant growth and have found that while low NO_2 concentrations (0.1 µl/L) did not significantly affect plant height, The study found that 0.5µl/L NO_2 considerably accelerated the leaf growth of Populus Deltoides and Populus Nigra Italic a, but a greater NO_2 concentration (1 µl/L) significantly inhibited the stem growth. The seedlings were 1-year-old Buxus Sinica seedlings. After being subjected to 0.85, 2, 4.25, and 9.4µl/L NO_2, Arabidopsis thaliana plants showed acute, evident leaf damage before dying. Even though those plants suffered considerable damage when exposed to NO_2 concentrations ranging from 2 to 4.25 µl/L, there were no appreciable variations in leaf growth or chlorophyll (Chl) content. As a result, we determined that the NO_2 fumigation concentration should be 6 µl/L (Sheng et al., 2019).

Impact of SO_2

Stress circumstances, especially air pollution, modify plant morphological, physiological, and biochemical processes by preventing net photosynthesis, slowing down development, and producing immediate observable damage (Ashraf and Harris, 2013). One of the first biological processes impacted by elevated SO_2 concentrations is photosynthesis; plants in these conditions show an initial reduction in photosynthetic rate and an increase in respiration rate (Gheorghe and Ion, 2011). According to Verma and Singh (2006), the effects of SO_2 on physiological processes are linked to stomatal responses. This is probably because stressed plants are unable to seal their stomata appropriately. Moreover, SO_2 has an impact on chlorophyll levels and carbon allocation, both of which have an impact on plant development and productivity and modifies the pace of photosynthetic reaction and the distribution of photosynthates, which impacts plant growth. Additionally, it modifies membrane permeability and alters the structure of the cell membrane. The ratio of carbon gain to water loss is a plant's water usage efficiency, or WUE. According to Swanepoel et al. (2007), prolonged exposure to SO_2, even at moderate concentrations, lowered WUE and chlorophyll content. On the other hand, WUE was elevated by high concentrations and brief SO_2 exposure. Environmental stress is known to have an impact on chlorophyll concentration). There is consensus that a drop in chlorophyll concentration can be a sign of SO_2 damage (Haworth et al., 2012). A plant's degree of harm from absorbing SO_2 is categorized as either acute or chronic. While long-term absorption of SO_2 at threshold concentrations results in chronic harm, acute injury is produced by high concentrations of SO_2 absorbed within a brief period of time. Nevertheless, it interferes with the electron transport chain and impairs thylakoid activity at high concentrations, which results in the collapse of physiological systems. Some have proposed that the pace at which SO_2 is absorbed determines the extent of SO_2 harm. Through the roots in the soil or the leaves in the atmosphere, SO_2 can enter the plant tissues. Plant leaves absorb atmospheric SO_2 through stomata, which guard cells can open or close. Increased SO_2 concentrations typically result in stomatal alterations; in particular, prolonged high SO_2 concentrations tend to induce stomata to close.Guard cells absorb sulfur after being exposed to SO_2 and become incapable of opening or closing their stomata. Consequently, SO_2 modifies the synthesis and distribution of photosynthates, which impacts plant growth. The reproductive process in plants can be hampered by the suppression of photosynthesis caused by high sulfur levels, perhaps resulting in fewer flowers or fruits (Hetherington and Woodward, 2003).

CH_4 emission

Methanogenesis is the process by which bacteria create methane. The creation mechanisms for methane, which is found in rocks and soil, differ from those of other fossil fuels. Methane is derived from ancient biomass. Methane emissions originate from both natural and manmade sources. The oceans, termites, and wetlands are the primary natural sources. Three-quarters of methane emissions come from natural sources. Livestock farms and landfills are examples of human sources. Nonetheless, the production, consumption, and transportation of fossil fuels constitute the primary source. Sixty-four percent of methane emissions originate from sources related to humans.Paddy fields account for 91% of methane emissions, with animal husbandry and the burning of agricultural wastes contributing less than 2% and 7%, respectively. When coal, natural gas, and oil are produced and transported, methane is released into the atmosphere. Methane emissions can also be attributed to the decomposition of organic waste in municipal solid waste dumps, livestock, and other agricultural processes. higher frequency of physiological conditions such blossom end rot and tip burn. Early maturity of citrus, grapes, melons, and onions is a result of rising temperatures. Citrus fruit set is low because of the warm weather. Many spring-flowering plants, like mangos, began to bud up to 4 days early for every

1°C increase in the average spring temperature following two recent warm periods. The hilly mountain region of Himachal Pradesh, where apples and other temperate crops are traditionally grown, was found to be suitable for cultivation because it consistently experiences the ideal temperature for fruiting and flowering. However, as global warming continues, this temperature may eventually rise to a point where it is no longer suitable.

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

Climate-smart horticulture is not a single, all-encompassing agricultural technique or technology. According to Malhotra (2014), this method necessitates site-specific assessments in order to find appropriate production technologies and techniques that may address the various issues that agriculture and food systems face concurrently and comprehensively. Although the form, breadth, and scale of climate change vary among different countries and sites, it is a worldwide phenomenon. Therefore, local analysis, planning, and administration are needed to address the concerns of climate change and the difficulties that result from it. In order to effectively address the issues, it is necessary to assess and comprehend how climate change is affecting both annual and perennial horticultural crops at the regional level. This can be done by managing innovation and the evaluation and improvement of technology (Malhotra and Srivastava 2014).

Simulation models for impact assessment

Using modeling methods for impact analysis for different horticulture crops will be helpful when developing adaptation and mitigation strategies. In India, there aren't many good simulation models available for horticulture crops (fruit and vegetables), possibly with the exception of coconut and potatoes. The Info Crop model has been modified for tomato and onion crops, and its validation for various agro-ecological zones is ongoing (Naresh Kumar et al, 2008). Large fruit trees and bushes pose challenges in studies examining the direct effects of many factors on growth, development, and yield in controlled environments due to their perennial nature. Prioritizing the development of simulation models for significant horticulture crops such as mango, grape, apple, orange, citrus, litchi, guava, etc. calls for creative approaches. Development of crop simulation models for horticultural crops in India is now a priority area of research.

Production system management

The focus should be on using the suggested production technologies to increase water efficiency and adjust to the dry, hot weather. It is necessary to employ tactics like shifting the dates of sowing or planting in order to counteract the anticipated rise in temperature and periods of water stress during the crop-growing season. Utilizing soil amendments to increase soil fertility and improve nutrient uptake, as well as adjusting fertilizer application to improve nutrient availability (Srivastava et al. 2014, Malhotra and Srivastava 2015). The two most crucial interventions are conserving soil moisture reserves and providing irrigation throughout crucial phases of crop growth (Malhotra 2016). Soil moisture conservation is aided by crop management techniques such as mulching with crop waste and artificial mulches.Raised beds can be used to cultivate crops when heavy rains cause excessive soil moisture, which can occasionally become a serious issue. Vegetable production could be pursued with clear plastic rain shelters, which can lessen the direct effect on fruits that are developing as well as field water logging during the rainy season. Vegetables grown on raised beds during the rainy season will produce more because of better drainage and less anoxic stress on the root system. Vegetable scion cultivars would become resistant to soil-related environmental challenges such drought, salinity, low soil temperature, and flooding if they were grafted onto tolerant rootstocks (Chieri et al. 2008).

Carbon sequestration potential

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 accounted 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 t C/ha. With a 5,381 ha area, agricultural forestry has an overall mitigation potential of 81,750 t C. The highest profitability is seen in fruit orchard farm forestry, with an IRR of 29.92% (Ravindranath et al. 2007, Laxman et al. 2010).

Technological change for mitigating affect

Actually, grapes are a temperate fruit that are often grown in chilly climates, whether they are being grown for wine or for table use. Nonetheless, technological advancements in plant architecture and production system management have made it possible to grow grapes in tropical climates with the highest global output. Similarly, high temperatures in the mid-hill agroclimatic conditions may produce pollen desiccation and fruit shrivelling, which will diminish yield and increase crop failure. Chilling alone will also not be sufficient to trigger flowering in apples. These are the anticipated effects that give rise to the worries. However, there are countless examples to show how technologies have assisted in minimizing the effects of climate change. Alkalinity and salinity posed significant challenges to the effective cultivation of grapes, but the discovery of appropriate rootstocks has increased yield significantly. Potatoes, tomatoes, cauliflower, and cabbage are examples of thermosensitive crops that were only productive during lengthy days in a temperate climate. However, it is now feasible to achieve extremely high productivity even in subtropical and mild subtropical regions with greater temperatures because to the introduction of heat-tolerant cultivars and modifications in production system management (Singh et al. 2008, Malhotra and Srivastava 2014). These historical examples eloquently illustrate the notion that, with creative research, the threat posed by climate change could be turned into an opportunity. However, this will require the depiction of the change's expected course, its effects, and plans to lessen its negative effects. Today's biotechnology techniques could contribute to a quicker delivery of study findings.

Conclusion

Numerous experts' studies show how different horticultural crops may be affected by climate change. The measurement of the effects of differences in Numerous experts' studies show how different horticultural crops may be affected by climate change. The first stage in preparing the horticulture industry to develop adaptation strategies under climate change scenarios is quantifying the effects of temperature changes and surplus and limited moisture conditions. To investigate and evaluate the effects on specific crops under the main agro-ecological zones and growing seasons, coordinated efforts are required. Increased efforts should be made to create new cultivars that are suited for various agroecological zones with shifting climates. For annual crops, the adaptation tactics can be implemented quickly by utilizing a variety of cultivars and species, altering planting dates, or changing the season. However, when establishing and rearranging orchards, the longer-term effects of climate change must be taken into account. Therefore, a thorough analysis of how climate change is affecting perennial crops is required before pursuing any adaptation options.

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