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Climate change: Impact, adaptation and mitigation strategies in fruit crops

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Abstract
Global climate change and increasing climatic variability are recently considered a huge concern worldwide due to enormous emissions of greenhouse gases to the atmosphere and its more apparent effect on fruit crops because of its perennial nature. The changed climatic parameters affect the crop physiology, biochemistry, floral biology, biotic stresses like disease-pest incidence, etc. and ultimately resulted to the reduction of yield and quality of fruit crops. So, it is big challenge to the scientists of the world. Mitigation is the most important measures to reduce the devastating effect of climate change. Carbon sequestration has the crucial role to mitigate the effect. Fruit crops are highly potential for carbon sequestration. Likewise negative impacts of climate change is also reduce through implementation of adaptation that are relevant, robust, and easily operated by all stakeholders, practitioners, policymakers and scientists.

Keywords: Global climate change, climatic variability, greenhouse gases, fruit crops, perennial nature

Introduction

The temperature of Earth has been changing for a long time, mostly because of natural factors like volcanic activity, even if it has been reasonably steady for the last 10,000 years or so. However, more rapid changes have occurred during the 1900s, and these are primarily attributed to human activity. Global mean temperatures rose by 0.74 °C over the past century, and the most accurate projections indicate that they will rise by 1.8–4 °C by the year 2100. This will lead to more variations in rainfall and a greater occurrence of extreme weather events like heat waves, cold waves, droughts, and floods [18]. The human food supply is seriously threatened by climate change. Approximately 12% of the world's population is currently in risk of starvation, but a mere 2 to 3 degree Celsius increase in temperature might put an additional 30 to 200 million people at risk [47]. India's grain production is expected to decline by 10–40% by 2080–2100 as a result of global warming, according to the IPCC assessment [19]. Given that crop yields are strongly correlated with climate, food production will be especially vulnerable to climate change, which might result in a reduction of up to one-third in food yields in the tropics and subtropics [37]. Food security will be severely impacted in the coming decades by the drastic changes in agricultural yield and geographical distribution brought about by climate change, especially rising temperatures, changed rainfall patterns, and climate variability. The most frequent weather conditions that fruit growers have encountered over the last ten or so years. Any crop's quality and production can only be achieved by meeting its ideal climate conditions. Crop physiology, biochemistry, floral biology, biotic stressors like disease-pest incidence, etc. are all impacted by the altered climate conditions, which ultimately lead to a decrease in fruit crop yield and quality. Therefore, it presents a significant challenge to global scientists.

Impact of climate change in fruit crops

Quantitative evaluations of the possible effects of climate change on crop output have been presented in several research. The following lists the effects of climate change as determined by numerous studies.

Flowering, fruiting and fruit dropping

The most crucial phases of all fruit crops, which are controlled by the climate, are flowering and fruiting. In many fruit crops, altered climate conditions disrupt pollinator activity and pollen viability, which in turn affects pollination, fruit setting, and flowering patterns. In Gujarat, unseasonable rains followed by a severe dew attack during the flowering season resulted in an 80–90% loss in mango production. This decreased fruit setting, increased fruit drop at the pea stage, and raised the incidence of sooty mould and powdery mildew in mangos [52]. Similarly, Gujarat's mango output was much lower in 2008–09 due to a 2 °C increase in temperature during the flower induction phase in December, which appears to have a negative impact on flowering and, eventually, mango crop productivity [32]. In 2009, the truly disastrous impact was also seen in Gujarati mangoes. The temperature continued to be harmful to the stages of flowering and fruit setting. During flowering, the temperature ranged from 33 to 36 °C. In South Gujarat, the flowering was cut down to 85–90%, whereas in Saurashtra, it was cut down to 65–70%. In terms of test and size, the fruit's quality was also going to decline. Additionally, it was discovered that increased relative humidity levels led to higher levels of powdery mildew and mango hopper infestation. Compared to 7.0 t/ha, the state average production decreased to 2.59 t/ha [51]. High temperatures and increased CO_2 reduced strawberry fruit output by 35% and 12%, respectively, at low and high nitrogen levels. At high temperatures and higher CO_2, fruit yield was reduced due to the smaller umbel size and fewer inflorescences during flower induction [38]. In contrast, the lowest fruit retention (2.68%) in custard apples was noted in 2008. It might be because of the warmer temperatures, lower humidity, and greater rain that occurs in June and July; more rain tends to cause more fruit to fall [53].

Physiological disorder

Many fruit crop physiological disorders, such as mango's spongy tissue, fruit cracking, custard apple's black spot, flower and fruit abscission, etc., are more noticeable as a result of the high temperature. Additionally, air pollution increased the prevalence of some physiological illnesses, such as black tip mango, and dramatically reduced the production of numerous fruit crops. Because the barren soils under clean culture had mean soil surface temperatures as high as 52.40 °C, the mango fruits collected from clean cultivation exhibited 15.55 and 18.33 percent occurrence of spongy tissue under Paria and Ghadoi conditions, respectively [21]. On the other hand, the rate of respiration and transpiration affects fruit temperature, which affects the typical ripening processes of fruit and results in the development of spongy tissue [17]. In addition to increasing sunburn and cracking in apples, apricots, and cherries, high temperatures and moisture stress also cause litchi fruit to burn and crack as it reaches maturity [23]. The highest percentage of black spots (35.63%) on the fruit's skin in custard apples was reported in 2009. This could have been caused by the high wind speed that year [53].

Crop duration

A crop's maturity or longevity indicates a crucial physiological process that has a direct impact on the yield and quality of the fruit. The different aspects of climate change also changed how the fruit matured. As temperatures rise, crops will develop more quickly and mature earlier, changing the timing of their production [16]. Due to strong respiration rates and warm temperatures, citrus fruit in lowland tropical regions matures quickly and does not have enough time to collect large TSS. The fruit's acidity swiftly decreases, causing the soluble solids/acid ratio to rise abruptly, and it soon becomes dry and insipid [56]. The Economic Times claims that because grape harvest is beginning two weeks earlier than in the past, the consequences of climate change and global warming are clearly visible [49]. In contrast, Greece had earlier grape harvest dates, primarily due to variations in the country's highest and lowest temperatures [11]. Similarly, in the current climate of the Baltic States, strawberry flowering time shifts usually occur between mid-May and mid-June (weeks 20–24). In the past, however, it occurred a week or two later (weeks 21–26), and in the future, bloom events could occur as early as the end of April (weeks 18–22) [4].

Shifting of crop belt

Existing plant species and types would relocate to new latitudinal bands with more hospitable conditions if the average global temperature rose. Therefore, crops that were formerly fruitful in one place might no longer be so, or the opposite may also be true. In India, apple production has shifted from lower elevations to higher elevations as a direct result of these climate changes [39].

Disease and pest

Climate change and rising CO_2 levels in the atmosphere may also have an indirect influence on crops by affecting disease and pests. According to evidence, pests like aphids and weevil larvae react favourably to higher CO_2 levels and altered climate conditions, which also raises the risk of new incursions. Mangos are less susceptible to fungal diseases like anthracnose and powdery mildew in hot, dry climates because spores are quickly rendered inactive by sunlight, low humidity, and temperature extremes (below 18 °C or above 35 °C) [26, 46, 2]. Morning relative humidity had a negative link with the hopper population and a very negative correlation with flower bugs, thrips/leaf, and thrips/inflorescence, according to the correlation analysis of weather conditions and mango inflorescence pests. The populations of flower bugs and thrips/inflorescences were significantly correlated negatively with the minimum temperature and evening relative humidity, whereas the populations of thrips/leaf were correlated negatively with both [6].

Irrigation water

Climate change is thought to have a greater impact on agricultural demand, especially for irrigation water. The necessity and timing of irrigation may change if the climate at the field level changes. Demand may rise in response to rising dryness, while demand may decrease if soil moisture content increases during key seasons. The need for yearly irrigation for fruit crops will rise—not due to increased evaporation, but rather because trees grow more quickly over the course of a year when atmospheric CO_2 levels are higher. Around 80% of the decline in apple output was attributed to a lack of irrigation water, 20% to the high rate of apple evaporation, and a reported drop in chill unit hours in Himachal Pradesh's apple-growing regions [45]. According to projections, the majority of India's irrigated lands will need more water by 2025, and global net irrigation needs will rise by 3.5% to 5% by 2025 and 6% to 8% by 2075 compared to the pre-climate change scenario [35].

Projected beneficial impacts of climate change

In addition to their detrimental effects, rising temperatures and atmospheric CO_2 levels can benefit some crops. For example, the rate of photosynthesis in C4 plants increased in comparison to C3 plants as temperatures rose [55]. In contrast, it was found that C4 plant species rapidly become saturated as CO_2 concentrations increase, whereas photosynthetic responses in C3 species continue to increase throughout a range of several hundred ppm CO_2 [43]. According to the NPCC report, farmers in temperate regions have benefited from climate change because the apple belt has moved 30 km upward (northward) due to temperature increases, and new apple-growing areas have emerged in Lahaul and Spitti and the upper reaches of the Kinnaur district of H.P. that were previously unsuitable for them. In lower elevation regions, farmers are switching from growing apples to growing kiwis, pomegranates, and vegetables [28]. Cool temperatures are the primary regulator of the mango tree's floral induction. Therefore, floral induction would be negatively impacted by rising temperatures. However, in areas where temperatures are exceptionally chilly during blooming, rising temperatures would benefit pollen viability and fruit set as well as accelerate the growth of mango fruits. Due to a 1.5 ˚C increase in winter temperatures, the expected time needed for mango fruit development in Australia fell by 12–16 days. As a result, mango fruit was available on the market earlier than it has been for the past 45 years [29]. Climate change may also improve the quality of some fruit crops, such as pomegranates, where the hot and dry period of fruit development increases the concentration of proline in the fruit [15].

Mitigation

1) In order to permanently eliminate or lessen the long-term risk and hazard of climate change to human life and their properties, "climate mitigation" refers to actions taken to decrease or stop the emission of greenhouse gases that cause climate change or to improve the sinks of these gases with the aid of conscious practices. The following are the different ways that orchard crops can help reduce climate change.
2) Increase energy efficiency by using solar and wind power, reducing or eliminating tillage, and improving the fuel efficiency of farm equipment.
3) Management of fertiliser, manure, and biomass can be achieved by using slow-releasing fertilisers, nitrification inhibitors, minimising the usage and manufacturing of synthetic fertilisers, and preventing the leaching and volatilisation of nitrogen from fertilisers during storage and application. Nimin, coated Ca-carbide, neem cake, neem oil, and thiosulphate34 are the next best nitrification inhibitors after Dicyandiamide (DCD), which effectively reduces nitrous oxide emissions (13–42%). On the other hand, dicyandiamide reduces cumulative N_2O emissions by 24.18–32.55% when combined with organic manures and urea [25].
4) Utilising organic fertilisers, reducing tillage, preventing soil compaction, utilising biochar, cover crops, intercropping, and other cropping systems are all ways to manage soil to increase soil carbon (%). The lowest soil organic carbon (SOC) stock was found in bael orchards (18.55 t/ha), while the highest was found in lemon orchards (38.92 t/ha), followed by mango (33.11 t/ha), ber (29.28 t/ha), aonla + aloe (27.74 t/ha), guava (27.70 t/ha), kinnow (21.90 t/ha), phalsa (21.74 t/ha), and shahtoot (21.08 t/ha) (13). In contrast, the coconut and pineapple cropping systems had the highest soil organic carbon (1.30%) up to 15 cm soil depth, while the rice and teak agroforestry systems had the highest above-ground and below-ground carbon densities, at 52.47 and 13.12 t/ha, respectively (48,5). Agrisilvicultural systems (ASS) sequestered the highest carbon tonnes per hectare (tree + intercrop) (12.36 to 47.87 t/ha), while Agri-silvi-horticultural systems (ASH) and Agri-horticultural systems (AHS) were the most viable agroforestry systems based on NPV (Net Present Value), Benefit Cost Ratio (BCR), Equivalent Annual Income (EAI), and compounded revenue [30].

Carbon sequestration

Carbon sequestration, also referred to as carbon dioxide storage, is the process of taking carbon out of the atmosphere and storing it in reservoirs. In nature there is mainly three way to sequestrated carbon dioxide: 1. Geological sequestration refers to the subterranean storage of CO_2 mostly in deep, unmineable coal beds or depleted oil and gas reserves. 2. Ocean sequestration is the biological and solubility-based storage of CO_2 in the deep ocean by phytoplankton. 3. Terrestrial sequestration is the process by which CO_2 is stored in soil and plant biomass through photosynthesis. In addition to providing farmers with food and revenue, fruit orchards play a significant part in the terrestrial sequestration of carbon through photosynthesis and the storage of carbon in tree biomass, including trunks, foliage, branches, roots, and soil. It was discovered that trees with dense foliage and broad, clustered leaves were superior at sequestering CO_2 [20]. With 203.62 t/ha, the santol plantation has the highest carbon sequestration value of the three, followed by the rambutan and mango plants [23]. However, in the case of the different pooling area, the soil recorded the highest amount of carbon sequestration, followed by the understory, fruit trees, roots, and litter. Mango has an average equivalent CO_2 of 16.8 t/ha while Aonla has an average of 18.7 t/ha.27 and the largest carbon stock (8.33 t/ha) and above-ground biomass (18.51 t/ha) in mango plantations [10]. In the mango agrosystem, the above-ground carbon stock density was 3.591 t/ha, but in Northern Ghana, the soil organic carbon was 29.484 t/ha (50). In walnut trees that were 4 to 14 years old, the above and below ground carbon sequestration potential was 0.26 t/tree and 0.067 t/tree, respectively, while the mitigated carbon and carbon stock in guava total biomass were 1.43 to 40.54 Mg ha^{-1}, 0.26 to 7.75 Mg ha^{-1}, and 0.48 to 13.66 Mg ha^{-1}, respectively [41, 12]. According to estimates, the total above-ground biomass carbon stalk per hectare was 33.07 kg C/ha for aonla, 30.6 kilogramme C/ha for mango, 36.96 kg C/ha for tamarind, 12.86 kg C/ha for sapota, 83.1 kg C/ha for ramphal, and 73.5 kg C/ha for custard apple [7]. Anand, Dahod, Patan, and Junagadh districts' net carbon sequestered in their current agroforestry systems over a 30-year simulated period was 2.70, 6.26, 1.61, and 1.50 Mg C ha–1, respectively. Teak had the highest carbon stock and equivalent CO_2 (35.84 t/ha and 131.54 t/ha, respectively), followed by coconut, sapota, and mango [42, 3].

Adaptation

Simply put, adaptation refers to the actions taken to modify capital, procedures, and practices in response to the reality or threat of climate change. It also includes responses in the decision-making environment, such as modifications to institutional and social structures or changed technical options that may impact the ability or potential for these actions to be implemented. The variety in climate and other environmental conditions, as well as cultural, institutional, and economic factors and their interactions, result in a vast array of agricultural techniques. This indicates that a wide range of adaptation options, frequently variations of current climate risk management, are accessible for little adjustments to current agricultural systems. Implementing adaptation assessment frameworks that are applicable, reliable, and simple for all stakeholders, practitioners, policymakers, and scientists to use is an essential part of this strategy. The agriculture sector can implement the following adaptation strategies to deal with future climate change.

1. Crop-based adaptation by modifying rootstock or crops that are climate-ready
2. Cropping systems, intercropping, alternative crops, crop diversification, and moving crops to other locations are all examples of cropping patterns.
3. Adaptation based on cultivars/varieties
   a) creation of climate change-resistant or tolerant cultivars, varieties, and rootstock.
   b) Planting various crop kinds or variations
4. Modifying crop management practices
   a) Changing the sowing or planting date, modifying the cropping season, and producing and marketing horticulture crops during off-season
   b) Using liquid, customised, or sustainable fertiliser
   c) Zero tillage, tillage techniques to enhance soil drainage, etc.
   d) Putting in place new irrigation systems or enhancing current ones, such as drip irrigation
   e) Enhancement of weed and crop residue control, as well as modifications to land use management techniques
   f) Efficient use of resources
   g) implementing resource-saving technologies and novel farming methods (such as fertigation, fruit bagging, etc.). Using brown paper and a scurting bag to bag mango fruits at the marble stage resulted in the highest fruit retention (%), but using a newspaper bag produced the highest fruit weight and fruit free of spongy tissue 14. Using prgmen bags to bag pomegranate fruits was lowering the incidence of sunburn and fruit breakage.
   h) Improved pest and disease management
5. Mulching improves the microclimate, microbial activity, soil health, and soil moisture retention. In comparison to control36, the plastic mulch increased the yield percentage of papaya (64.24%), mango (45.23%), banana (33.95%), ber (27.06%), guava (25.93%), pineapple (14.63%), and litchi (12.61%). White-on-black plastic mulch was found to increase the maximum runner plant yield in strawberries at warmer locations, such as Kinston and Reidsville, while black plastic mulch was found at cooler mountain locations, such as Laurel Springs [44].
6. Utilising anti-traspirants, such as chitosane, kaolin, etc., which reflect heat radiation from plant parts, can lower the temperature of fruit and leaf surfaces and other chemicals while also reducing water losses through transpiration. In comparison to the other treatments, the banana treated with 2% anti-traspirant chitosane had the highest average finger weight, average hand weight, and bunch weight [1]. Because kaolin effectively minimises sunburn in pomegranate fruit9 and terra alba lowers the average fruit and leaf temperature when compared to control 31, the treatment with terra alba yields the highest quality pomegranate fruits. When compared to other frost reduction techniques, the Bordeaux mixture was the most effective way to lessen frost damage to grapes cultivated in a moderately cold region [54].
7. In addition to altering the orchard's microclimate, wind barriers or shelter belts shield the orchard from wind erosion and other natural disasters, and they also offer a haven for pollinating insects. Fruit crop orchards with wind breaks around them had the lowest mortality rate of frost-affected fruit plants (2.97 to 30.81%), whereas those without such barriers had the highest mortality rate (up to 91.43%) [41].
8. Weather forecasting, farmer crop insurance programs, and GIS use
9. Utilising water harvesting technologies and recycling solid waste and wastewater in agriculture

Conclusion

Changes in the global climate are probably going to put strain on the fruit production system and make it more difficult to meet future fruit output goals. Although these changes are natural, we can regulate them by implementing a number of mitigation strategies that lower the concentration of gases in the atmosphere that cause climate change. Fruit crops are particularly effective at reducing these gases because they sequester carbon through photosynthesis. Currently current adaptation techniques can lessen adverse effects in the short term, but only to a certain degree. Therefore, we must act quickly to improve our capacity for adaptation by expanding adaptation research, developing our capacity, changing policies, and putting in place adaptation assessment frameworks that are applicable, reliable, and simple for all stakeholders, practitioners, and policymakers to use.

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