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5. Impact of Climate Change in Fruit Crops

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Abstract:

Climate change is a major worldwide issue that poses serious dangers to agricultural systems, particularly fruit crops. The influence of climate change on fruit crops is examined in this abstract, with an emphasis on phenology, quality, and disease and pest dynamics. Fruit crop phenological variations have been reported in response to changing climatic circumstances. Warmer temperatures and shifting precipitation patterns can all have an impact on when flowers bloom, buds break, and fruits mature. These alterations can upset the delicate balance between the plant and its environment, resulting in decreased fruit set, changed growth patterns, and lower yields. Such phenological variations can have a domino impact on the ecological interactions within fruit crop ecosystems. Climate variation also has an impact on the quality of fruit harvests. Fruit size, colour, flavour, and nutritional content can all be affected by rising temperatures. Furthermore, changes in temperature can impact the sugar-to-acid ratio, affecting the flavour and general appeal of fruits. These quality variations can have serious consequences for both producers and consumers, resulting in economic losses as well as possible effects on human health and nutrition. Climate change also has an impact on the dynamics of pests and illnesses in fruit crops. Pest populations can grow as temperatures rise, causing greater agricultural damage. Similarly, changed precipitation patterns can foster the spread of fungal and bacterial infections. These variables not only cause direct output losses, but they also increase reliance on chemical pesticides, posing environmental and health problems. Assessment of adaptation and mitigation techniques is required. This chapter addresses the effects of climate change has an impact on a various fruit crops, as well as strategies for dealing with these potential issues.

5.1 Introduction:

Long-term changes in global weather patterns and temperatures caused by human activities, particularly the use of fossil fuels and deforestation, are referred to as climate change. The

Earth's temperature has always varied naturally throughout time, but the current fast warming is primarily due to greenhouse gas emissions caused by humans. According to the Intergovernmental Panel on Climate Change (IPCC), the Earth's temperature might rise by up to 4°C by the end of the century, causing sea-level rise, extreme weather events, and other consequences that would have far-reaching consequences for human civilizations and ecosystems. According to NASA statistics from October 2020, the CO_2 concentration in the atmosphere grew quickly to 400 ppm in 2014, with a recent record of 415 ppm (Source- https://climate.nasa.gov/vital-signs/). Between 1906 and 2005, air temperature rose by 0.74°C (IPCC 2007a). In 2019, the most recent annual average anomaly was 0.99°C. By 2100, global temperatures are forecast to rise by up to 6°C, while CO_2 concentrations are likely to rise by 550 to 850 ppm [21]. Depending on future development, the average temperature in the Indian subcontinent will rise by 0.5 to 1.2°C by 2020, 0.88 to 3.16°C by 2050, and 1.56 to 5.44°C by 2080, according to the IPCC [59]. The principal drivers of climate change are unpredictable rainfall patterns and unexpectedly high or low temperature regimes, both of which have far-reaching consequences for agriculture in general and horticulture in particular.

5.2 Climate Change and Fruit Crop Production:

Climate, an essential environmental element, has a substantial influence on fruit crop production. Plant physical characteristics such as vigour, canopy development, and reproductive traits such as fruiting ability and fruit size reduction, as well as quality characteristics such as less colour development, low juice content, decreased shelf-life, and increased pest attack, all contributed to poor fruit quality and low fruit production [25]. Temperate crops' ability to adapt to unexpected weather changes over a specific time of the growing season in any historically inhabited temperate crop region is jeopardised, potentially resulting in serious production issues in the near future [4]. The spread of existing pests, diseases, and weeds, as well as the increased likelihood of incursions into new crops, as well as the appearance of minor pests, illnesses, and physiological problems such as sunburn, fruit cracking, and tip burn. Appropriate cooling hours are critical for optimal vegetative development and fruiting in temperate fruit species. In temperate fruit orchards, a lack of chilling hours leads to inconsistency in bud break and fruiting [66]. In the Shimla district's central hills, the trend is to abandon potato and apple production entirely. In this regard, the snowfall pattern and apple output in Himachal Pradesh have been confirmed. Apple production per acre decreased from 10.8 to 5.8 tonnes. This is only one instance of climate change. As a result of climate change, various abiotic factors are arising, which has an influence on several horticultural fruit crops and their physiological, anatomical, morphological, and biochemical features. Temperature, drought, salinity, floods, CO_2 concentration rise, and insect-pest outbreak have the greatest influence on fruit output [17].

5.2.1 Climate Change's Impact on Fruit Crop Phenology:

One of the well-known effects of climate change is a shift in the period of plant growth activity, known as phenology. Climate change has affected the vegetative and reproductive phases of fruit plants. Flowering is an important stage in fruit development that influences yield and productivity. Pome fruit flower buds may wholly or partially abscise in mild winters, resulting in smaller flower bud clusters that resemble leafy spurs. Climate change has influenced flowering, fruiting, and, eventually, yield [60]. In the case of apples, a shortage of chilling time resulted in incomplete flowers and poor fruit set [24]. Chilling hours had an impact on both the quality and quantity of flowering and fruit set. An rise in early spring temperature of 0.45°C/decade (1973-2009) resulted in a 1.6-day/decade advance in apple and pear blossoming [18]. The following crops saw comparable results in various areas throughout the world. In France, a rise in average growing temperature of 2-3°C (1964-2009) increased blooming, veraison, and harvest by 13-19 days in grapes [64]. Veraison for the cultivars "Riesling" and "Gewurtztraminer" will be advanced by up to 23 days by 2100 [13]. Due to temperature changes in February and March, the peak blooming period of the cherry tree has migrated earlier by 5.5 days in the last 25 years. Temperature has risen by 1.8°C in the last 25 years [39]. In apple, insufficient cooling needs during warm seasons produce various phenological disruptions such as late blooming, extended flowering durations, and a longer interval between flowering and harvest [14]. A significant relationship was discovered between blooming development and changes in maximum and lowest temperature throughout time in numerous locations around Iran (Kerman, Shiraz) [16]. In citrus fruits, flowering progresses at rates of 3.15-3.39 days/°C for Kerman and 4.3-4.47 days/°C for Shiraz. Hermaphrodite flowers were more closely associated with greater temperatures following bloom initiation [52]. The warm (15.9°C) temperature, which is 3-5°C above than normal, resulted in undeveloped pistils [53].

5.2.2 The Influences of Climate Change on Fruit Crop Physiology:

A. Temperature Effect:

The physiological activities of plants are regulated by temperature. Imbalanced temperatures have the following consequences. For example, 1. Heat stress, 2. Inadequate chilling for temperate crops 3. Pollination activity disruption. Heat stress promotes evaporation, which causes stomatal closure and a decrease in CO_2 inflow, eventually driving respiration and reducing photosynthesis. Chilling hours will be reduced by 30 to 60% by 2050 and up to 80% by 2100, according to the National Climate Assessment 2014. The Warmer climatic circumstances were found to have a substantial impact on flowering, fruit set, yield, and quality in peach cultivars. In mild winter years, flower abortion occurs, resulting in a decreased fruit output [3]. Temperature stress has a significant impact on pollination activity, which contributes for 35 percent of global food supply [31]. Plant-pollinator interactions are hampered by temporal (phenological) and geographic (distributional) misalignments. Temporal changes are already visible, as Apis mellifera increased their activity time before the flowering maxima of their preferred feed species. Areas in developing countries are altering geographically [18]. Crop plants that are incompatible with themselves, pollinator restricted, or pollinator specialised are more sensitive to this hazard. A flower bud can become vegetative in warm night time temperature [12]. Because of their prolonged flowering time, fruit crops are more vulnerable to climate change. The hormones required for tree growth and development are altered by temperature. Mango and litchi have already shown early flowering and crop harvesting. In January, low temperatures (11.5 °C), high humidity (>80%), and gloomy weather all delay panicle emergence, although low temperatures during panicle development diminish hermaphrodite flowers [10]. Mango malformation is common in locations with harsh winters and may benefit from a warmer temperature. Mango, banana, papaya and sapota output and productivity stayed found to be negatively connected to temperature and rainfall during a ten-year period (2007-2017) in Navasari district in Gujarat (India). [63].

- **Drought:** Drought is a common occurrence in dry and semi-arid areas with irregular precipitation, and it is defined as a absence of precipitation [32]. Water stress may be particularly vital to yield response throughout phenological stages and is critical in planning irrigation within large limited water zones [27]. Stress affects perennial fruit tree yields by diminishing the amount of fruits and the cell size of surviving fruit before to or during the flowering and post-blooming seasons [48;49]. Drought reduces banana growth, yield, and productivity by reducing the plants' capacity to photosynthesize. Lack of adequate water at the finger growth stage leads bunches to shorten [62]. African banana production losses are mostly caused by an inadequate supply of water, which has a detrimental influence on nutritional intake [65]. Drought stress lowers finger numbers during floral initiation in bananas, whereas it correlates to poor filling following emergence [37]. Moisture stress has been shown to reduce the size and quantity of tomatoes. The occurrence of blossom end rot and sunscald was greater in the very stressed plants. Irrigation treatments had a substantial impact on TSS content, which increased with stress level as fruit water content dropped [7]. Long-term water stress causes fruit and flower drop in avocado during blooming and fruit development. Plants cultivated on sandy soils with low irrigation capacity are more vulnerable to drought stress than plants planted in clay soils. Freshly planted orchards are particularly sensitive to drought stress due to poor root system development and fast growth of foliage in the early stages [32].

B. Rainfall:

Rainfall is another significant aspect that has arisen as a result of climate change. Crop output is reduced by uneven or no rainfall, particularly in rainfed areas. Heavy rainfall in locations with inadequate drainage reduces soil oxygen availability, which kills the growth of helpful microorganisms, and water-logged conditions promote the spread of insect-pests and illnesses, reducing crop output. Rainfall during the flowering period reduces fruit set, growth, and production. Inadequate rainfall influences pests, resulting in low fruit output [38]. Fruits in heavy rainfall areas are susceptible to illnesses such as anthracnose in mango fruit during the maturity stage [47]. Rain during flowering washed off the pollen from the flower's stigma, As a result, fruit setting is poor or non-existent. In Gujarat, unseasonal rain followed by a heavy dew assault reduced fruit setting, increased fruit drop, and increased the frequency of sooty mould and powdery mildew by 80-90 percent. [52]. Extended water stress cycles result in yield losses ranging from 10% to 40%. Water-logging cycles lasting more than two days are beginning to limit Cape gooseberry leaf area. After four days of exposure, the stem diameter decreases, as do bud initiation, fruits, and flowers [2].

C. CO2 Effect:

The physiological status of a plant is affected by increased CO2 concentration. It is essential for photosynthesis, which creates the plant's biomass. In response to increased CO2, raising net photosynthetic proportion in grapes while reducing stomatal conductance enhances innate water usage efficiency in Portugal. In general, they observed that increasing ambient

CO_2 levels increases yield irrespective of any positive or negative effects on grape maturity. Even though they were well into reproductive maturity (17 years), sour orange trees were more susceptible to increasing CO_2 levels. At the time of harvest the trees cultivated with CO_2 enrichment (350-650 ppm CO_2) exhibited significantly higher root biomass, leaf biomass, branch biomass, fruit biomass, and total biomass than the trees grown in natural circumstances [29]. The heat generated by CO_2-related global warming in open habitats, as well as soil water evaporation, are anticipated to offset the benefits of enriched CO_2 for plant biomass production, resulting in shorter growth periods, reduced yield, and more yield variance [57].

5.2.3 Climate Change Impact on Quality of Fruits:

Quality requirements are critical in order to obtain a profitable price in the export market. Changing climatic circumstances have an influence on the optimal conditions for appropriate pigmentation and secondary metabolite formation, both of which are required to yield excellent fruits. Temperature fluctuation may also contribute to perfect growth conditions. 'Kent' strawberries have higher antioxidant activity during warm days (25°C) and mild nights (18-22°C) [67]. Climate change has also been demonstrated to have negative consequences, such as earlier ripening in California near the end of the century, which may result in lower quality grapes in the region [20]. Due to browning and berry burn, incidental heat shocks (over 35°C) resulted in the loss of 50% of the berries [30]. In terms of quality, simulated climate change scenarios had a greater influence on technical (primary metabolism) maturity than phenolic (secondary metabolism) [28], Rising temperatures reduce the quality of grape wine production by hastening the maturation period of the grapes and decreasing acidity and colour. Fruit availability may be shortened as a result of quicker maturation and ripening [34] Mandarin oranges grown in direct sunlight (35°C) were 2.5 times firmer than those grown in shadow (20°C) because direct sunlight reduces the activity of cell wall enzymes (cellulase and polygalacturonase) during growth, which slows ripening [69].

Grapes are a well-known example, with bunches exposed to direct sunlight ripening before those matured in shaded positions inside the canopy [68]. High temperatures have also been reported to hinder the development of the fruit's colour. When the temperature rises and unseasonal rains fall, downy mildew damage ensues. When fruits produced at higher temperatures were stored at 3°C, there was a breakdown incidence, which is attributable to the lower calcium content in the fruits grown at higher temperatures [5]. Sunburn may occur when fruits, such as litchi, are exposed to excessively high temperatures for a lengthy period of time or even for a short period of time during their growth and development [40].

Greater watering requirements owing to increased evaporation, as well as speedier tree development due to faster heat unit accumulation, are the causes of the reduced fruit sizes and anthocyanin content in litchi [42]. Apple fruit marketing relies heavily on the red hue of the fruit. One of the most important factors affecting the development of apple fruits' red hue is temperature. In discs treated at 20 and 25 degrees Celsius compared to 30 degrees Celsius, the red colour density was higher [45]. Due to extreme temperature and moisture stress, sunburn and fruit breaking are becoming increasingly prevalent in apples, which has drastically decreased fruit quality [50]. High temperatures has tens water core incidence in pear [55].

Table 5.1: Impact of Climate Change on the Nutritiousness of Fruit

Fruit crop	Climate variable	Nutritional quality variables	observations
Apple	Humidity, Temperature and solar radiation	Sugar-acid ratio, Anthocyanin and Vitamin-C content	Apples now have higher anthocyanin concentrations, vitamin C contents, and sugar-acid ratios thanks to rising temperatures and decreased sunshine.
banana	Rainfall, Temperature and solar radiation	Carbohydrate content and concentrations of micro-nutrient	The average fruit weight and content decreased whereas P, Mg, and Ca levels increased as the average daily temperature increased. The impacts of temperature, rainfall, and soil type on quality variables were all different.
Grape	UV and Sunlight exposure	Anthocyanin, total phenolic and tannin content	As grapes are exposed to more UV rays and sunshine, the anthocyanin, total phenolic, and tannin content of wine likewise rises.
Grape	Rainfall and Temperature	Phenolic and Anthocyanin content	Temperature increases were adversely linked with grape anthocyanin and phenol levels. Temperature affects phenolic content more when rainfall is below normal.
Citrus (orange)	Soil salinity	Content of micro-nutrients in leaves	As soil salinity increased, the micronutrient composition of sour orange leaves on different rootstocks changed. Ca^{2+}, K^+, and Mg^{2+} concentrations decreased, P concentrations stayed constant, while Na^+ and N concentrations increased.
Citrus (orange)	Frost	Proteomic and metabolic profiles	The cold has impacted protein levels as well as primary and secondary metabolites. Some fruit constituents were expressed more fully as a result of the frost, whereas others were expressed less fully.

5.2.4 Fruit crop Climate variable Nutritional quality variables observations:

Apple Humidity, Temperature and solar radiation Sugar-acid ratio, Anthocyanin and Vitamin-C content Apples now have higher anthocyanin concentrations, vitamin C contents, and sugar-acid ratios thanks to rising temperatures and decreased sunshine. Banana Rainfall, Temperature and solar radiation Carbohydrate content and concentrations of micro-nutrient The average fruit weight and content decreased whereas P, Mg, and Ca levels increased as the average daily temperature increased. The impacts of temperature, rainfall, and soil type on quality variables were all different.

Grape UV and Sunlight exposure Anthocyanin, total phenolic and tannin content As grapes are exposed to more UV rays and sunshine, the anthocyanin, total phenolic, and tannin content of wine likewise rises.

Grape Rainfall and Temperature Phenolic and Anthocyanin content Temperature increases were adversely linked with grape anthocyanin and phenol levels. Temperature affects phenolic content more when rainfall is below normal.

Citrus (orange) Soil salinity Content of micro-nutrients in leaves As soil salinity increased, the micronutrient composition of sour orange leaves on different rootstocks changed. Ca^{2+}, K^+, and Mg^{2+} concentrations decreased, P concentrations stayed constant, while Na^+ and N concentrations increased.

Citrus (orange) Frost Proteomic and metabolic profiles The cold has impacted protein levels as well as primary and secondary metabolites. Some fruit constituents were expressed more fully as a result of the frost, whereas others were expressed less fully.

5.2.5 Climate Change's Impact on Fruit Crop Area Suitability:

The yield, flowering, and quality of tropical fruits vary from year to year due to changes in the rainfall distribution pattern [52]. Warming has enlarged the tropical zone during the last several decades, [36], emphasising the need of additional areas for tropical foods. A 1°C rise in temperature can drastically affect the region suitable for tropical fruits. Several fruit crop favourable areas may become somewhat suitable, and new suitable ones may emerge. Temperature rises are likely to have a greater impact on the reproductive systems of these crops. A 0.7-1.0°C temperature increase may modify the current zone suitable for quality production of Dushehari and Alphonso mango cultivars [51]. The best environment for a mango variety Dushehari suffers greatly with a 1°C increase in temperature, but Alphonso (a mango cultivar) is most likely restricted to the Ratnagiri area because to its resilience to shifting environmental conditions [9]. Certain findings were drawn from a research of worldwide banana production and its appropriateness under climate change scenarios, such as an increase in suitable regions owing to temperature rise, mostly in areas with an average temperature of 24°C [1]. According to studies of 24 places throughout the world, all of the sites indicate a linear rise in temperature, making climate change a problem for civilization It is expected that the region with tropical growth climate would rise, whilst present tropical zones will experience serious climatic challenges [11].

5.2.6 Climate Change's Influence on Pest and Disease Incidence in Fruit Crops:

Pest and disease incidence in fruit crops has increased as a result of climate change. Changes in flowering time and temperature can result in the introduction of novel pests, minor pests becoming severe pest status, and the breakdown of resistance. According to the National Research Centre for Banana annual report 2012, Sigatoka disease has reached dangerous levels in Maharashtra, where it was never considered a problem before, as a result of climate change. Stormy weather increases the likelihood of bacterial gummosis in pome and stone fruits. Climate change has the ability to alter pathogen development stages and rates, as well as host resistance and pathogen-host interaction physiology. Tropical insects (physiological optima) are more sensitive to warming than higher latitude insects [17]. A decrease in the number of specific vector insects in tropical climates might reduce the occurrence of specific viruses such as citrus leprosy (mealy bug), papaya ring spot (aphid), pineapple wilt (mealy bug), and others [15].

Temperature and rainfall patterns, for example, have a direct impact on the lifecycle of many insect pests. Climate change might have an impact on regional distribution, population growth rates, generation numbers, overwintering, developmental seasons, crop-pest phenology synchrony, pest invasion by migratory pests, and interspecific interactions [46]. When the temperature was raised from 20 to 35°C, fruit fly development increased in mango cv. Chausa. With the possibility of a third generation of codling moth, preventive measures (e.g., pesticides) would need to be strengthened and extended in order to manage this additional generation, meaning an increased risk of chemical residual effects on fruits [21]. Climate change has increased disease incidence, water consumption, and insect infestation, resulting in a rise in input costs in Pakistan's Punjab plains citrus orchards [44].

5.3 Adaptation Strategy to Mitigate Ill Effects of Climate Change Fruit crops:

Adaptation is vital, but mitigation is also required since even if all emissions were halted, temperatures would continue to rise for decades before stabilising. If the rate of rise is not slowed, it will reach several disastrous tipping points, hastening climate change to the point where adaptation may become scarce [61]. Integrating adaptation and mitigation is the most effective method for increasing both adaptation and mitigation [23]. There is enough room in agriculture, land use, and forestry to address adaptation and mitigation at the same time, since each give's chance for the other. Soil organic carbon amplification is the most important adaptation and mitigation strategy in tropical production systems because it not only has the biggest agriculture-based mitigation potential but also provides resistance to climate change

A. Change of Crop and Varieties:

One of the most important adaptation measures is crop and variety change in response to climate change. Crop cultivars that can survive both biotic and abiotic stressors provide increased climate resilience. Identifying more adaptable cultivars as well as a variety of cultural practises may assist producers in maintaining current output. Drought-tolerant cultivars and types that may avoid stressful periods by having a shorter fruiting season must be developed/identified. Drought-tolerant Pomegranate hybrid Ruby, Annona hybrid Arka Sahan, and Grape root stock Dogridge (Vitis champine) have all been discovered to be promising. Different races and genetic bases must be investigated and tested [43]. The origin of fruits should be investigated for climatic adaptability. For example, mono-embryonic type mango might be studied for a land-logged environment in northern India with a well-defined winter, whereas poly embryonic type mango could be evaluated for a coastal climate for adaptation to changing climate [36].

B. Canopy Management:

Canopy management improves yields and fruit quality by increasing leaf and fruit exposure [33]. When done correctly, it reduces resource competition and enhances crop physiological processes. It is critical in several situations, like Litchi. The primary goal of training in younger plants is to form the canopy and establish a sturdy structure that provides increased resistance against heavy winds. Training and trimming mature plants seeks to maintain desired form and maximise tolerable surface area.

Pruning helps retain the vitality of aged plants/orchards that might otherwise acquire senility. Pruning has been shown to stimulate shoot start. Rising CO2 levels in the atmosphere are anticipated to promote canopy development, which may provide a more favourable micro-climate, more sensitive tissue, more inoculum interception, more potential for infection, more polycyclic infection, and a radiation shield for inoculums. If all leaves removed during training or pruning are integrated into the soil, and 50% of hard biomass is utilised as lumber with a life of more than 30 years, pruning and training are predicted to have a net mitigating impact. [56], By removing 25% of the canopy, researchers discovered an improvement in light utilisation in mango.

C. Efficient Water Management:

Coconut has had the highest rate of drip system adoption among crops, followed by banana, grape, papaya, pomegranate, mango, and sapota [10]. Even though rain fall has increased slightly, water availability is expected to be limited as more intense rain produces more runoff. An effective irrigation method, such as drip irrigation, will save substantial water that may be utilised to extend the watered area. More favourable soil moisture combined with increasing CO2 levels may induce increased biomass production and soil-carbon enrichment [16].

D. High Density Planting (HDP):

Tropical fruits have high adaptability and mitigation potential since they not only produce more but also collect biomass and soil carbon per unit area. Terrestrial carbon uptake in a well-managed high-density perennial planting can be up to 1.5 times that of regular planting in one life cycle. HDP is already being used selectively in mango, guava, banana, citrus, pineapple, pomegranate, papaya, cashew, and coconut. These successes should be replicated for other tropical fruits such as litchi, longan, and so on. Mango, guava, and citrus trees can be planted at 2.5 m x 2.5 m, 3 m x 3 m, and 1.8 m x 1.8 m instead of 10 m x 10 m, 6 m x 6m, and 6 m x 6 m. Canopy control is critical to success, but future high-density plantings must use dwarfing rootstock, inter-stock, and scion varieties. HDP success necessitates a combination of canopy management and growth regulators [32].

E. Protected Cultivation:

Protected cultivation with net houses or poly houses offers the benefit of modifying the microclimate and exposing the crop to fewer weather extremes. Increased CO2 levels in the growth environment can also help to improve photosynthesis [29]. Protected farming has the extra benefit of reducing insect and disease damage as well as wild animal harm [30]. In India, over 40,000 hectares of protected agriculture are employed, largely for annuals or as a nursery for perennial crops.

5.4 Conclusion:

Climate change has had an important role on fruit crop phenology, quality, and susceptibility to diseases and pests. Temperature changes, rainfall patterns, and extreme weather events have thrown off the timing of blooming, fruit ripening, and overall crop growth, resulting in decreased yields and poor fruit quality. Furthermore, rising temperatures and changed precipitation patterns foster the development of diseases and pests, creating further difficulties to fruit production. Implementing adaptive strategies such as breeding resilient crop varieties, improving irrigation and water management, implementing integrated pest management practises, and adopting sustainable farming techniques can help mitigate the adverse effects of climate change and ensure the long-term sustainability of fruit crop production.

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