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Climate change and its impact on fruit crops

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Abstract

Climate change is an observed reality. The change in natural vegetation and ecology is one of many adverse effects resulted from the climate change. One of the best documented effects of climate change is the changing timing of plant growth activity, known as change in phenology. Alteration in between the duration of vegetative and reproductive phase is taking place due to climate change. In most fruit crops, generally higher temperature decreased the days interval required for flowering by reducing the vegetative phase. Mandarin exposed to direct sunlight (35 °C) is 2.5 times firmer than those on the shaded side (20 °C). Decreased cell wall enzyme activity under higher temperature during growth and development delays ripening. It also affects chemical composition of fruits with variable precipitation and moisture stress trends. The increase in temperature from 0.7-1.0 °C may shift the area suitable presently for the quality production of Dashehari and Alphonso varieties of mango. Rise in temperature by 0.2 °C may result into dramatic reduction areas suitable for development of red colour on guava. Change in the flowering times in temperate regions leads to ecological consequences such as introduction of new insect-pests, etc. Warming is most deleterious for tropical insects than species at higher latitudes. Despite the rising atmospheric CO_2, food production in future is uncertain with global warming and altered precipitation. Loss in plant diversity and area suitability will further increase the problem. Under such threats in global fruit production a plan based on strategic scientific assessment of such impacts should be quantified with adaptation and mitigation approaches.

Keywords: Climate, ecological, food security, global warming, phenology, productivity

Introduction

Climate change, as defined by UNFCCC is 'a change that is attributed directly or indirectly to human activity which alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods'. Climate change is projected to cause an increase in temperature, variations in rainfall, and an increase in frequency of extreme events such as heat, cold waves, frost days, droughts, floods, etc. Various plant processes like vegetative growth, flowering, fruiting and fruit quality are highly vulnerable to climate changes. Two major parameters of climate changes that have far reaching implications on plants are more erratic rainfall patterns and unpredictable high temperature spells which are consequently expected to reduce crop productivity. Drought reduced fruit set and increased fruit cracking in pomegranate and litchi. Temperature increase affects photosynthesis directly, causing alterations in sugars, organic acids, flavonoid contents, firmness, and antioxidant activity. Rise in atmospheric carbon dioxide levels persistently affected post-harvest quality causing sugar content reduction in potatoes and tuber malformation incidence of common scab. An increase in atmospheric temperature and change of rainfall pattern affected the banana cultivation in some countries. In various fruit crops, moisture stress and high temperature during flowering strongly influences the pollen and ovule quality and consequently the fruit set and yield. The promotion of stigma and stamen sterility in papaya is mainly because of the higher temperature, which caused flower drops as well as sex changes in female and hermaphrodite flowers. Flower drop is quite common in mango, guava, litchi and other fruits, if low temperature prevails during flowering. Studies have clearly shown that the population abundance, geographic range and pollination activities of important pollinator species like bees, moths, and butterflies are declining considerably with changing climate. Higher temperature during fruit growth and development increased the incidence of several physiological disorders like spongy tissue and black tip in mango, cracking of fruits, granulation in citrus, etc. Pest ecology of certain crops is changing due to climate change. Fruit fly in guava, carambola, citrus, etc. is becoming alarming due to hot and humid conditions. Warm and humid conditions are also favorable for pests like beetles, bugs and other sucking pests and diseases like mildew, blight, etc. Development of new varieties with higher yield potential and resistance to multiple stresses (drought, flood, salinity) should be the key to maintain yield. Improvement in germplasm of important tropical and subtropical fruit crops for heat stress tolerance should be one of the targets of breeding programs. Location specific soil and water conservation models, protocol for organic farming, conservation horticulture, development of biotic and abiotic stress tolerance rootstocks, etc., are some of the strategies to mitigate the impact of climate change.

Impacts of Climate Change on Fruit Crops

Impact on phenology

Time change of different physiological activities i.e. phenology is one of the most pronounced effect of climate change. In temperate fruits, flower induction is deeply influenced by temperature, especially low temperature, however, strong interaction between genotype, photoperiod and temperature interactively control flowering. As per study conducted by Wolfe *et al*., there was an advance in spring phenology ranging from 2 to 8 days for the woody perennials in north-eastern USA during period 1965 to 2001 and a qualitatively consistent and similar phenology shifts with a warming trend have been reported for other mid and high-latitude regions. An earlier date of full bloom of up to 10 days was observed in apple 'Boskoop', 'Cox's Orange Pippin' and 'Golden Delicious' when comparing the last 20 years with the previous 30 years, which is less than the 14 days reported generally for Germany. Advancing trends in bloom dates of many trees indicate that dormancy breaking processes are indeed changing most likely in response to climate change.

Impact on patterns of blooming

According to Vedwan and Rhoades, climatic changes alter the pattern of blossoming, bearing and, therefore, fruit yield and the quality of apple deterioriate under Western Himalayan condition of India. The greater rise in winter and spring (January to March) temperatures lead to earlier flowering, which coincides with the time of spring frost resulting in a remaining risk of frost damage to apple flowers. In temperate climate areas, frost can also represent the main cause of weather related damage to crops. Apple and other temperate fruit are vulnerable to spring (late) frosts. During the bloom stage, a single event with temperatures going a few degrees below zero is sufficient to damage flower buds or even kill them. While light frosts result in the deterioration of fruit quality, severe frosts threaten the harvest itself.

Impact on dormancy and chilling requirement

The plants use the dormancy mechanism to protect its sensitive tissue from unfavourable climatic condition. There might be alteration in the adaptability of many temperate fruit crop in the near future due to rapid climate change, and severe productivity problems might arise as well. Commercially successful cultivation of many fruit and nut trees requires the fulfillment of a winter chilling requirement, which is specific for every tree cultivar. Lack of chilling as in mild winter conditions result in abnormal pattern of bud-break and development in temperate fruit trees. Eventually, warming may affect over-winter chill requirements of temperate tree fruits and require replacement by new cultivars or species. This process ultimately results in varying crop sizes and maturity stages at the time of harvest, which can substantially reduce yield and fruit quality. Melting of ice cap in the Himalayan regions will reduce chilling effect required for the flowering of many of the horticultural crops like apple, cherry etc. For cultivars with chilling requirements above 1000 chilling hours such as apples, cherries and pears, very few locations with safe chilling levels were found to exist today, and modeling results project that virtually none will exist by mid-century.

Impact on pollination

Climate change, with a potential to affect every component of agricultural ecosystems, is reported to impact bees at various levels, including their pollinating efficiency. The changing climate scenario has contributed in significant reduction in the population of the pollinating insects. If the temperature is either very low or very high there is no fertilization, thus affecting fruit set. For fruits that are cross pollinated such as walnuts and pistachios, insufficient chilling can reduce pollination leading to reduced crop yields. The optimum temperature for pollination and fertilization in temperate fruits like apple, pear, plum, cherry etc. is between 20-25 °C. Low temperatures and rainy or foggy conditions had observed to have a negative effect during pollination in sour cherry in USA.

Impact on pest and disease incidence

Climate change could alter stages and rates of development of pathogen, modify host resistance and physiology of host-pathogen interactions. Climate change could lead to Changes in geographical distribution, Changes in population growth rates, Increased overwintering, Increase in the number of generation, Extension of developmental seasons, Changes in crop-pest synchrony of phenology, Changes in interspecific interactions of insects and Increased risk of invasion by migrant pests (Parmesan, 2007) [6]. In addition to direct impact of climate change on apple productivity, it has also aggravated infestation of some diseases and pests resulting in more losses in yield.

Impact on Fruit Quality

The increase in temperature from 0.7-1.0 ˚C may shift the area suitable presently for the quality production of Dashehari and Alphonso varieties of mango. Rise in temperature by 0.2 ˚C may result into dramatic reduction areas suitable for development of red colour on guava (Rajan, 2008) [8]. Mandarin exposed to direct sunlight (35 °C) is 2.5 times firmer than those on the shaded side (20 °C). Decreased cell wall enzyme activity under higher temperature during growth and development delays ripening.

Impact on Post-harvest quality

According to Moretti *et al*., [5] temperature variation can directly affect crop photosynthesis, and a rise in global temperature can be expected to have significant impact on the postharvest quality by altering important quality parameters such as synthesis of sugars, organic acids, antioxidant compounds, peel colour and firmness. Grapes had higher sugar content and lower levels of tartaric acid when grown under high temperatures.

Approaches to Mitigate Impact of Climate Change

- **Dormancy avoidance**

The methods which can prevent the plants from entering into dormancy condition helps in bud burst without requiring chilling temperature. Griesbach observed that dormancy can be induced artificially by defoliating the trees just after the harvesting. Luedeling stated that the defoliation of the trees enable them to resume their annual crop cycle without chilling requirements and this type of practice has made the production of temperate fruits possible in countries like India and Kenya. Bud break in case of apple, Japanese plum, apricot, and pear can be broken artificially by a sequence of treatment like desiccating the trees followed by manual defoliation of the tree, renewed irrigation, and rest-breaking treatments. Chemical defoliation of peach by zinc sulphate and of apple by copper sulphate or urea enhances sprouting of buds. Late pruning and delayed irrigation strongly influenced bud break in peach in Mexico.

- **Manipulation of the chilling requirement of temperate fruit trees**

Once the tree cultivars are selected and planted in the orchard, it is required that they remain in production for decades. The need to anticipate and adapt to climatic changes is very much urgent for growers of tree crops. Even the already established commercial varieties of fruits might perform poorly in an unpredictable manner due to aberration of climate. This has led to the development of cultural, mechanical and chemical practices to alleviate the problem associated with insufficient chilling.

- **Low chill cultivars**

This is the most feasible solution to the problem of insufficient chilling. However, it is very difficult to breed low chill cultivars. Modern biotechnological aspects in mapping the genetic determinism of chilling are required to boost up the breeding process with a view to develop appropriate cultivars for all major fruits within a reasonable time span. Re-evaluation of the fruit varieties as per the indicated climate changes is imperative for planning a new orchard. Introduction and adaptation of low chilling cultivars of crops like apple, peach, pear and plum in certain areas of lower hills and North Indian plains where they could be grown commercially. The low chill cultivars of some temperate fruits are listed below (Rai *et al.*) [7].

Fruit crops	Low chill cultivars	Chilling requirement
Apple	Anna, Mayan, Tamma, Vered, Tropical Beauty, Parlin's Beauty, Schlomit, Michel, Neomi.	<800
Peach and Nectarines	Flordasun, Flordared, Sunred Nectarine, Sun Gold, Saharanpur Prabhat, Shan-e-Punjab, Sharbati	<500
Pear	Gola, Pathernakh (Sand Pear), Leconte, Kieffer, Punjab Nectar.	<150
Plum	Santa Rosa, Jamuni, Alubokhara, Alucha purple, Titron, Satluj purple, Kala Amritsari	--
Apricot	New Castle, Early Shipley, St.Ambroise, Kaisha, Chaubattia Alankar	--

- **Heat treatment**

Temperature is often considered the most important factor influencing phonological phases of fruit trees in temperate climates. Higher temperatures enhance biochemical reactions, which consequently prolong the growing season and influence phonological phases of individual plants. Heat shock proteins (HSPs) have been found in various plants and in some cases they have been found to increase with the chilling. Tamura *et al*., found nine HSPs to be accumulated when the trees were exposed to short-term high temperature treatment (45 °C for 4 hours) and were responsible for inducing bud break in the floral buds of Japanese Pear 'Nijisseiki'. Similarly, pear plants when treated with water at 45 °C for three hours, bud burst was induced. Chandler showed that bud burst was induced in apple trees when they were exposed to 44-46 °C for six hours of a single or on two consecutive days in July, October and November.

- **Evaporative cooling**

The other approach to induce bud burst is to increase chilling hours by evaporative cooling of the buds under endodormancy period. Evaporative cooling helps in reducing the bud temperature under mild winter condition and thereby increasing the number of chilling hours required for proper bud burst. Sprinkling with water to provide evaporative cooling during rest period had been found to advance the blooming of 'Flordagold' peach and 'Sungold' nectarine by 7 days. Allan *et al*. reported the synergistic effect of Dormex and evaporative cooling by intermittent overhead sprinklers during the peak hot hours of the day in improving the bud-break and yield. Uzun and Caglar delayed the blooming in pistachio by means of evaporative cooling that involved the sprinkling of water to cool fruit buds in order to delay their development. Overhead irrigation has successfully been applied in Israel for cooling buds during the hottest hours of the day.

- **Breaking rest period by chemical application**

Insufficient chilling during winter period usually results in delayed and erratic blooming and foliation of deciduous fruit and nut trees. The rest can be broken under certain conditions by using chemicals such as DNOC oil or cyanamide. Cutting *et al.* reported that the use of hydrogen cyanamide and DNOC oil treatments resulted in 3 and 4 weeks earlier bud-break in 'Granny Smith' apple, respectively. Petri treated apple trees with Mineral oil (4-6%) + DNBP (dinitro-butyl-phenol) at 0.13% to 0.2%, and found that Mineral oil at (4%) with DNBP (0.12%) increased lateral bud break rate by 40%.

Conclusion

The climate change affects not only the winter chilling of fruit crops but it also affects the other aspects like increase in the incidence of physiological disorders, pollination failure and phenology. Despite the rising atmospheric CO_2, food production in future is uncertain with global warming and altered precipitation. At present, there is limited information regarding realistic impacts of pests and diseases in a hanging climate, which otherwise may influence future food security. The effect of climate change is not only productivity but also impaired fruit quality. Loss in plant diversity and area suitability due to climate change will further increase the problem. As global warming is considered inevitable, endeavour should thus be undertaken to manipulate the chilling requirements of the temperate fruit crops by various means. Under such threats in global fruit production a plan based on strategic scientific assessment of such impacts should be quantified with adaptation and mitigation approaches.

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