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Fruit Production Under Climate Changing Scenario in India : A Review

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Abstract Global warming and climate change are the major concerns today for the mankind. The extreme weather events are universal ; weather events like increased global temperatures, melting the polar ice, increased sea water levels, drought and floods, hailstorms, tornados, causes severe loss to the crops and human beings. The present day cultivars / varieties may perform very poorly in an unpredictable manner due to aberration of climate. Alimost all fruit crops are generally cultivated under open field conditions, with the climate change commercial production of these crops may severely affect. Increased temperatures effect on establishment, growth and yield of the majority of fruit crops. Due to high temperature physiological disorder of fruit will be morepronounced like Spongy tissue of mango, fruit cracking of litchi, flower and fruit abscission. Air pollution also affects the yield of several fruit crops and increases the intensity of certain physiological disorder like black tip of mango. Very low winter temperatures effect on same tropical fruit crops like banana, causes chilling injury and choke throat. Hence there is a need to protect these valuable crops for sustainability against the climate change scenario. To sustain the productivity, modification of present horticultural practices and greater use of greenhouse technology are some of solutions to minimize the effect of climate change. Development of new hybrids, cultivars of fruit crops tolerant to abiotic and biotic factors, producing good yield under stress conditions, as well as adoption of hi-tech horticulture and judicious management of resources will be the main strategies to meet this challenge.

Keywords Horticulture, Climate, India, Production.

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Introduction

India with diverse soil and climate comprising several agro-ecological regions provides ample opportunity to grow a variety of horticultural crops which form a significant part of total agricultural produce in the country comprising of fruits, vegetables, root and tuber crops, flowers and other ornamentals, medicinal and aromatic plants, spices and condiments, plantation crops and mushrooms. It is estimated that all the horticulture crops put together cover nearly 23,417 thousand hectares area with an annual production of 2,83,468 thousand tones [1]. Though, these crops occupy hardly 8% of the cropped area in India with approximately 30% contribution in agricultural GDP. After independence there has been seen marked growth in area and production of fruit crops but on the other hand productivity has left far behind as compared to advanced countries. The low productivity is mainly attributed to several factors including environmental, physiological and biological. But over the years, environmental changes playing a significant role like erratic rainfall, snowfall, droughts, increase in temperature, hail storms resulting in variation in the fruit production. A significant change in climate at global and national level is certainly impacting horticulture and affecting our fruit production and quality. But understanding of impact of climate change on perennial horticultural production system and the potential effects on fruit quality have drawn a little attention of researchers.

Increase in temperature is likely to impact the atmospheric processes, and the occurrence of weather abnormalities like floods, droughts, cold and heat waves is likely to increase in ensuing decades under the projected climate change scenarios. The super cyclone in 1999 across the Orissa coast adversely affected the cashew plantations in sandy soils. All fruit crops suffered heavily due to unprecedented cold waves in 2002–2003 across north Indian states. At the same time temperate fruit crops such as apple, plum and cherry gave high yield due to extended chilling. In contrast the heat wave in March 2004 in the same belt adversely affected apple, tea, potato and vegetables. Potato and vegetables matured early and heavy crop losses were noticed due to abnormal increase in temperature as result of heat wave [2]. The prolonged droughts during summer adversely affected the crops like cocoa, black pepper, coconut, coffee, tea and cardamom along west coast in 1982-1983 and 2003-2004 [3]. Increase in night temperature in several parts of the country during winter 2010 adversely affected mango flowering. Cyclone Phailin in 2013 across the Odisha and Andhra coast adversely affected the cashew, coconut and banana plantations. The strong cyclone Hudhud on October, 2014 also made more loss to farmers. Therefore, there is a need for proactive measures for sustenance of horticulture against the occurrence of cold and heat waves, floods and droughts as well as sea level rise as a part of "National Climate Resilient Horticulture" under projected climate change scenario as their frequency is likely to increase in the ensuing years.

Climate change scenario across India

The increase in annual mean temperature over different zones of the country varied between 0.2°C and 0.78°C with an overall increase of 0.49°C for the country as a whole. The West Coast of India is warmer (0.73°C) followed by the Western Himalayas (0.7°C). The North-East India (0.63°C) and the East-Coast of India (0.52°C) in terms of mean annual temperature. The least increase (0.2°C) in annual mean temperature was noticed across the Northwest India over a period of 103 years, commencing from 1901–2003 [4].

There was a marginal increase in annual rainfall as well as seasonal rainfall during the south–west monsoon and post monsoon season since last 194 years (1813–2006) for the country as whole. A similar trend was noticed in all the zones in annual and south-west monsoon rainfall except in North-East India. Rainfall is likely to increase between 5% and 25% all over the tropics in the next 25—30 years on account of climate change according to climate change projection models.

The West Coast of India is warmer followed by North-East India and the western Himalayas. The warming over the North West India is mild, and cooling was noticed rather than warming during winter. Although there had been a distinct rise in temperatures since 1970, the rate of increase in the last 15 years was higher in the country compared to the preceding 15 years. While the rise in temperature was 0.2°C during 1901 to 2000, it was 0.4°C between 2001 to 2010, according to Indian Meteorology Department. Out of 13 warmest years, 8 years fall during the decade 2001—2010. 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009 and 2010 were the warmest years in the recent decade. The increase in mean temperature during the recent decade (200—2010) was 0.6°C. The years 2009 and 2010 were recorded as the warmest in the country since 1901 [5].

Impact of climate change on fruit production

Climate change will have both positive and negative impacts on fruits in tropical regions. In regions where the prevailing temperatures are already high, further increases in temperature will adversely affect the yield and quality of fruits. In regions where cold temperatures are one of the primary factors limiting crop production, temperature increases will be beneficial. The impact of temperature change can be clearly seed from the fact that the northern parts of India are warmer than the southern parts, with a general increase of 36°C over the base-period average [6, 7]. Studies carried out on perennial trees have to be contiguous and long range. Since experiments are carried out for short periods, these studies more often than not have become pointers rather than conclusive.

In the peninsular regions of India, it has been noticed that flowering was enhanced by a month in mango, thus affecting the fruit maturity and season of harvest. In the case of crops like guava, which has adapted very well to both tropical and sub-tropical climate environments, changes in temperature have contributed to postponing of fruiting season. Apart from the postponement of fruiting season, it is also true that in several cases fruiting and ultimate set have been badly affected.

Under the influence of climate shift, both early and delayed flowering will be characteristic features in mango. As a result of variations in temperature, unseasonal rains and higher humidity, fruit trees show altered flowering trends. Delays in panicle emergence and fruit set have been noticed. Fruit set and availability of hermaphrodite flowers for pollination have an effect on yield due to pollen and stigmatic sterility. If panicle development coincides with an unusual cold spell, mango production will face several problems.

Early flowering in the sub-tropics may result in a low fruit set because of several abnormalities caused due to low night temperatures coupled with unseasonal rains. It can be generally seen that low day temperatures cause reduced pollinator activity resulting in poor fruit set. Late flowering also reduces the fruit set because of pseudo-fruit setting leading to clustering disorder. High temperatures during panicle development in mango speed up growth and reduce the number of days for effective pollination when hermaphrodite flowers are available, which may lead to unsatisfactory production. It is the authors' experience that unseasonal rains coupled with variation in temperature and humidity can make mango trees flower during offseason, but fruit set will be poor because of the showers. Rising temperatures cause desiccation of pollen and poor pollinator activity resulting in low fruit set and, ultimately, a poor crop [8].

In the sub-topics, low night temperatures (5—10°C) result in synchronous flowering. However, night temperatures of 10—18°C produce asynchronous flowering similar to that in the tropics. Climate changes may cause abrupt changes in night temperatures, which will cause asynchronous flowering in the cub-tropics and result in poor productivity. Flower buds exposed to cold temperature during night may change into vegetative ones under the warm night conditions.

In the tropics cool winters followed by a rise in day temperatures as summer approaches may result in poor flowering. Cool temperatures during inflorescence development reduce the number of perfect flowers [9]. Inflorescences, which emerge during the middle and end of the flowering season, have been reported to produce between two and seven times more perfect flowers respectively than the early breaking inflorescence. The increase in perfect flowers in the later emerging inflorescence correlates with higher average temperatures during the later part of the flowering season. In controlled environment studies, [10] found that low temperatures (15°C day / 10°C night) during inflorescence morphogenesis reduced the proportion of perfect flowers in mango. The reduction was found to be the greatest in a tropically evolved poly embryonic group of cultivars compared to those from a mono embryonic group. In warm temperatures, vegetative shoots were produced within 17 days of commencing treatments. These results indicate that floral induction is caused by cool temperatures and not by short photoperiods and that flowering is inhibited by warm temperature, not by long photoperiods [11, 12].

In papaya, higher temperatures have resulted in flower drops in female and hermaphrodite plants as well as sex changes in hermaphrodite plants. The promotion of stigma and stamen sterility in papaya is mainly because of higher temperatures. It has also been noticed that if flowering takes place under extremely low temperature conditions, flower drop is quite common in most fruit crops like mango, papaya, guava and other fruits. In grapes, degree-days are important in determining the timing of various phenological events where, a temperature regime of 10°C and temperatures between 28—32°C are most congenial. Variations in temperature cause alterations in the developmental stages and ultimately the ripening time. Under a higher temperature regime, the number of clusters per shoot was greater and the number of flowers per cluster was reduced. In the case of the variety Cabernet Sauvignon, maximum fruit set was observed at 20/15°C with no fruit set at 14/9°C or 38/33°C. The loss of ovule viability in the varieties Pinot Noir and Carignane at 35 and 40°C as compared to 25°C. The photosynthesis rate was highest in the temperature range of 20—30°C and the evapo-transpiration rate increased with temperature and was highest at 30—35°C. The partitioning of photosynthates within the leaf was affected as temperature increased leading to reduction in concentration of starch within the leaves of Cabernet Sauvignon vines.

The quality of mango variety Dussaheri drastically reduced with a 0.7–1°C increase in temperature as a result of climate change. However, not many changes were seen with an increase of 0.2°C while the future climate simulation by 2050 exhibited remarkable reduction in the area suitable for the variety. Another example was for Alphonso variety grown mainly in Ratnagiri area of western India with similar results was noticed. Climate based models indicate a shift of suitable area of this variety away from areas where it is presently grown commercially, particularly in the Ratnagiri area. Some of the areas of Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh where Alphonso is grown may become unsuitable for quality fruit production [13]. In the case of fruit crops like pineapple, the impact of temperature variations can be seen from studies where induction of flowering takes place because of reduction in temperature, short day lengths or both. The coincidence of long days with high temperatures results in irregular flowering, which goes to emphasize the role of temperature. In longan, over-winter has developmental problems such as small fruit size, severe fruit drop and cracking. Stressful temperatures of <15°C in young fruit stage reduce fruit growth potential and final size. Stressful cold, plus abrupt temperature fluctuations induce excessive fruit drop. Severe fruit cracking is related to cold and dry weather in the young fruit stage [14]. In the case of mandarins, low temperatures appear to have dual effects, releasing bud dormancy and inducing flowering. Potential flower buds have deeper dormancy than vegetative buds, and the first stages of flower initiation seem to occur before the winter rest period.

Effect of temperature changes on pest and disease scenario

A number of factors affect the pest and disease scenario in fruits. High temperatures coupled with high rainfall and humidity help in building up ideal conditions for the growth of a number of disease pathogens. For example, powdery mildew disease in mango caused by *Oidium mangiferae* Berthet is a sporadic but serious disease of mango inflorescence that can cause up to 80—90% losses of the crop in extreme cases. Optimum disease development occurs at 10—31°C and 60—90% RH. High humidity (85—90%), moderate temperatures (max temp of 25—26°C and min of 18—20°C) provided favorable condition for the initiation of disease [15]. Correlations between weather parameters like different maximum temperature regimes and sunshine hours had negative correlations with disease development, while minimum temperature, humidity and wind speed had positive correlations. Fruits harvested during humid conditions were more heavily infested but a small number of fungal agents were involved; *Colletotrichum gloeosporioides* and secondarily *Phoma mangiferae* played the main role [16]. In mango and guava, it has been observed that the incidence of fruit fly is much less at higher temperature regimes. However, a recent study conducted in India [17] shown that in mango cv Chausa the rate of development of fruit fly increased with the increase in temperature from 20—35°C. The percent larval survival, adult emergence and growth index also increased with an increase in temperature from 20—27°C and thereafter decreased up to 35°C. Thus a temperature of 27°C was found to be ideal for survival and development of the immature stage and reproduction of *Bractocera dorsalis*. Post-harvest treatment of fruits at 48°C for 60—75 minutes has given good control of fruit flies [18].

Impact of climate change on fruit quality

Although, it is true that higher temperature regimes generally result in the best quality fruits, excessively high temperature for extended periods of time are known to damage fruits. Excessively higher temperatures generally result in delay of fruit maturation and reduction in fruit quality of grapes. High temperatures also reduce color development. At 35°C pigment development was completely inhibited in Tokay and reduced in Cardinal and Pinot Noir compared to 20 or 25°C. Higher daily temperatures were also related to a decrease in color hue values, i.e., more red fruit.

In the case of guava, it has been observed that red color development on the peel of guava requires cool nights during fruit maturation. Varieties like Apple color, which have attractive apple skin color under sub-tropical conditions of North India, have red spots on the skin under tropical South Indian conditions. The areas suitable for production of red color guava were studied and observed that when mapped with the present climate database, an increase of 0.2°C in temperature resulted into dramatic reduction in the areas suitable for development of red color in guava, an increase of 0.5°C in temperature will reduce the areas drastically with the suitability probability of more than 97% to a very low level. Based on a future climate database, predictions show that areas with suitability percentage of less than 70% will be available for red color guava development. Areas suitable for red colored guava cultivation will be reduced dramatically because the minimum temperature during the coldest month may increase up to 1.9°C whereas the mean temperature of the coldest quarter will be 3.2°C higher than the existing temperature resulting in less red color development in guava fruits.

High temperatures also appeared to reduce monoterpenes (Muscatflavor) in grapes. Linalool, an important monoterpene was also highest at low temperature grown Tunisian grape cultivars [19]. Total soluble solids, fruit firmness and percentage dry mass were negatively correlated with temperature during fruit growth. However, the relationship varied with the cultivar [20].

Size and appearance, soluble solids content, total sugar content, total acids content and water content were greater and sugar to acidity ratio and vitamin C content were lower in pear fruits collected from the low temperature regions compared to high temperature regions. In Navel oranges the content of acidity was affected by low temperature leading to low TSS content. Among other climatic factors the rainfall in September and October had an obvious effecton the fruit soluble solids content where less rainfall in this period increased the soluble solids [21]. In papaya higher temperature coupled with higher moisture content will bring about higher TSS. This has also been observed in many of the fruit crops like mango and guava. Another notable example is that in passion fruit, sugar content in the juice was highest at 28/23°C and lowest at 33/28°C, sucrose accumulated more at 23/18 °C and glucose and fructose contents increased at higher temperatures.

In sub-tropical and tropical fruit crops, there is a direct effect of the temperature on the maturity and ripening of the fruits. When there is sufficient moisture, the TSS of the fruit increases with the temperature. However, in some fruits like passion fruit, increases in temperature do not increase TSS. Hence, the effect of different regimes of temperature can be different on different crops under sub-tropical and tropical environments. In the case of pomegranate, the aril color turns from red to pink. However, it is the genotype × environment interaction that ultimately decides the expression of a trait. The stability of the genotype to perform under different environment is the ultimate deciding factor in the expression of any trait. In fruit crops like guava, which are grown in the tropics as well as the sub-tropics, and in strictly tropical arid crops like pomegranate, certain genes responsible for skin color or pulp color are not expressed under certain environmental conditions. In mango under different temperature regimes, fruit size is affected. In the case of the Cavendish banana, development of the golden yellow color is affected under high temperatures, which is not the case with other cultivars. It has been decisively shown by the above examples that temperature is one of the main factors affecting gene expression for certain traits.

Impact of climate change on

Inputs (*availability and costs*)

Perennial fruit crops are very vulnerable to short-term shortages of irrigation water availability. More irrigation (water) will be required because of higher evaporative demand. This will increase the cost of purchasing water, if it is available and pumping water under hotter conditions. If drought conditions do become more frequent, or their severity increases due to climate change, then the lifestyle (or amenity horticulture) sector will be affected. More drought tolerant plants and more efficient irrigation techniques will be required for industry and consumers to be able to adapt. Climate change will increase the cost of labor for harvesting.

Cultural practices

An increasing incidence of ; out of season and extreme rainfall events, including consequent flooding, will affect the timing of cultural practices as well as the negative effects on yield and product quality. Increasing temperatures will impact greenhouse crop production, especially production in sub-tropical regions, where current summer temperatures restrict production to the cooler months of the year, because temperature thresholds are often exceeded. Aditional technologies for cooling greenhouses will be required for these production systems to continue. Greenhouse production in temperate (or high land) regions will be impacted less, and for summer production the impacts.

Marketing arrangements

Higher temperatures will change production and marketing arrangements between regions. Crops will develop more rapidly and mature earlier, taking less time from planting or fruit set to harvest.

Post-harvest costs

Increased costs of grading and marketing for susceptible fruit and vegetables will occur for removing increased amounts of blemished product. Reduced marketable yields associated with damage from sun burn, poor color development and pollination will also occur. Post-harvest cooling costs for most vegetable crops will increase as additional field heat will need to be removed prior to transport to market.

Increased productivity

Increases in temperature and CO_2 may increase yields of some crops, providing positive productivity outcomes. Large variations in response to increased CO_2 levels have been found across a range of horticultural commodities. Where positive responses have been found (e.g. potato, lettuce, avocado and citrus) increasing temperatures may offset any increased productivity.

Adaptation strategies for climate change

Breeding strategies

1. Pheno-typing of all important fruits genetic wealth to enhancing temperature, moisture stress and genetic enhancement for tolerance to biotic and abiotic stress.
2. Varieties and rootstocks will be evaluated under controlled mperate moisture tress gradient to identify suitable cultivars of all major fruit crops. Experiments on varietal evaluation will also be conducted under natural conditions at different altitudes / conditions (with natural variations in temperature and moisture falling under various agro-climate zones of the countries.
3. Marker assisted selection and development of transgenic having resistance to biotic and abiotic resistance.
4. Development of genotypes having resistance to heat and drought.

Agronomic management strategies

Assessment of the vulnerability and climate risks associated with temperate fruit production system in temperature, tropical and subtropical region and development of cropping systems under various agroclimatic conditions. Improvement in the irrigation and drainage systems. Development of appropriate tillage and intercultural operations. Planting time will adjust as per the climatic situations. Development of water harvesting techniques and crop diversification.

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Biotechnological innovative strategies

Molecular characterization for various traits in relations to biotic and abiotic stress. Transformation of plants from C_3 to C_4 plants. Gene pyramiding against biotic and abiotic stress. *In vitro* conservation of rare and useful species for future use.

Mitigation strategies for higher CO_2 / GHG

Assessment the carbon sequestration potential of perennial fruit crops production system. To participate in the international dialogue about greenhouse gas emissions management, global warming and sustainable energy development, ; Use of biofuel like diesel from Jetropa and Pongamia sp ; The development of nuclear energy ; The improvements in the efficiency of electricity generation, transmission and distribution ; The use of fuels with lower carbon content, e.g., natural gas, CNG, Gobber gas ; Fuel switching, Appliance efficiency and use of renewable energy ; Tree planting and forest management and waste processing.

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