Mini Review Article

IMPACT OF GLOBAL WARMING ON FRUIT CROPS IN INDIA

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ABSTRACT

Global warming is now becoming a worldwide concern; the rise of temperature has been felt much more clearly after 1990**.** Abnormality in climate patterns, induced by accelerated warming. Higher temperatures lead to a high rate of evaporation and dry conditions in some areas of the world. Perennial crops such as fruit trees have faced very serious damage due to climate change. Qualities of fruits have clearly changed. For example, peel colouring disorder, reduction of acid, softening and spoiling rapidly of fruits have been observed more frequently. As a result of rising temperature and decline in rainfall, the apricot and cherries are fast disappearing from some areas of Kashmir valley. In Himachal Pradesh, apple cultivation shifting towards to higher altitudes due to climate change, where in Uttarakhand; its cultivation has drastically been reduced. Therefore, some adaptation techniques to mitigate the effects of global warming have been developed. Problems and practical approaches against negative impacts of global warming on fruit crops are reviewed.

INTRODUCTION

The Earth's climate has always changed and evolved. Some of these changes have been due to natural causes but others can be attributed to human activities such as deforestation, atmospheric emissions from industry and transport, which have led to gases and aerosols being stored in the atmosphere. Climate change is now perceived to be the greatest threat to horticulture production and food security in the 21st century. The Intergovernmental Panel on Climate Change (IPCC) by means of the fifth assessment (2014) have been released to date has shown scientific evidence that, in the second half of the 20th century temperatures have increased, and these changes are driven to a considerable extent by increases in the concentration of greenhouse gases (GHGs) in the atmosphere. The IPCC has reported 0.5 to 1.2°C rise in temperature by 2020, 0.88 to 3.16°C by 2050 and 1.56 to 5.44°C by 2080 for Indian region depending on future development. Cimate change is projected to cause variations in rainfall, increase the frequency of extreme events like as heat, cold waves, frost days, droughts and floods etc (Sen *et al.*, 2015). An increase of 2°C in temperatures will pose a strong pressure on existing crop varieties. Climate is an important environmental factor which is affecting the production of fruit crops. Farmers' perception on crop-climate interaction underlies the impact of changed climatic conditions on blossoming, fruit set, yield, fruit quality and ecological ramifications (Singh *et al.*, 2010). Many fruit and nut crops do not provide a return on investment until several years after planting. Bloom times, frost dates, chilling hours, plant stress, disease incidence, and insect pressure are made uncertain by an unpredictable climate, growers of perennial fruit and nut crops will find it increasingly difficult to stay in business. Wheat or corn growers can decide from year to year whether to plant a little late or plant a little early or plant a different variety. But fruit growers can be locked in for decades once they've made a decision. Admittedly, the change requires to be managed through innovation, technology, evaluation and refinement, which should provide effectiveness to the policy. We have to visualize likely changes; factors associated with change and examine the possibility to mitigate the impact of climate change through effectively planned innovative research.

Impact of Global Warming

India is the second largest producer of Fruits after China, with a production of 93.71 million tonnes of fruits from an area of 6.46 million hectares (Anonymous, 2016). In India large variety of fruits are grown, of which mango, banana, citrus, guava, grape, pineapple and apple are the major ones. Due to raise in temperature, specific chilling requirements of temperate fruits will be affected hence dormancy breaking will be earlier. High temperature and moisture stress also increase sunburn and cracking in apples, apricot and cherries and increase in temperature at maturity will lead to fruit cracking and burning in litchi (Kumar and Kumar, 2007). In general, higher temperature (>30^{o}C), increases the rate of plant maturity in annual species, thus shortening the growth stages, during which developing fruits and suckers absorb photosynthetic products. The temperature below 10^{o}C leads to impedance of inflorescence and malformations of bunches. Chilling symptoms on leaves are not seen immediately but it may take 2 to 4 days to appear. Air pollution also reduce the yield of several horticultural crops and increase the intensity of certain physiological disorders like black tip of mango which is induced by coal fume gases, sulphur dioxide, ethylene, carbon monoxide and fluoride. Leaf production increases by one leaf per month for every 3.3 to 3.7^{0}C rise in minimum or mean temperature from 10-20^o C or 13.5 to 25^o C respectively.

Effect on pollination: Climate change, an emerging global phenomenon, with a potential to affect every component of agricultural ecosystems, is reported to impact bees at various levels, including their pollinating efficiency (Reddy *et al.*, 2012). 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 (Gradizel *et al.*, 2007).

Effect on dormancy and chilling requirement: Dormancy is a mechanism that plants use to protect sensitive tissue from unfavourable climatic condition (Campoy *et al.,* 2011b). The rapid climatic changes might alter the adaptability of many temperate fruit crops in the near future, and severe productivity problems might arise. Commercially successful cultivation of many fruit and nut trees requires the fulfilment 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 (Amegilo *et al.*, 2006). Eventually, warming may affect over-winter chill requirements of temperate tree fruits and require replacement by new cultivars or species (Stock *et al.*, 2010). This process ultimately results in varying crop sizes and maturity stages at the time of harvest, which can substantially reduce yield and fruit quality (Chandler *et al.*, 1942).

Effect on phenology: The change in the timing of different physiological activities i.e. phenology is one of the most pronounced effect of climate change (Cleland *et al.*, 2007). The analysis of phenological events for plants during the past several decades have been examined for quantifying a possible biological response to recent climate change (Parmesan and Yohe, 2003). In temperate fruits, flower induction is deeply influenced by temperature, especially low temperature, however, strong interaction between genotype, photoperiod and temperature interactively control flowering.

Effect on pest and disease incidence: Insect life cycle processes affected by climate and weather include life span duration, fecundity, diapauses, dispersal, mortality and genetic adaption. High temperature in spring results in faster reproduction rate, thus the increase in pest population is rapid (Patterson *et al.,* 1999). Efficacy of crop protection chemicals is affected due to changes in temperature and precipitation. In addition to direct impact of climate change on fruit productivity, it has also aggravated infestation of some diseases and pests resulting in more losses in yield (Gautam *et al.*, 2013). Dry and hot summer reduces the infection of Rhynchosporium leaf blotch and Septoria leaf spot diseases, but summer precipitation, particularly heavy storms, would increase the incidences of these diseases (Royle *et al.*, 1986).

Effect on post-harvest quality: 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 (Moretti *et al.*, 2010). Grapes had higher sugar content and lower levels of tartaric acid when grown under high temperatures (Kliewer *et al.*, 1970).

Effect on yield: In the first six weeks after the blossom cell division takes place in almost all temperate fruits crops. Temperature influences the amount of cells created in the fruit. The warmer it is, the more cells are produced and the bigger the fruits. Warmer temperatures are very beneficial for newer varieties. It is a disadvantage though for the apple cv. Cox's Orange; because the warmth produces too many cells per fruit and this results in fruit that is too big, too soft and goes off quickly. Fruit size is generally smaller, where low temperate occurs during spring which affects cell division in the post-bloom period. Over the last few years, there has been distinct slow growth in production and productivity of saffron in rain-fed areas of Kashmir valley but due to unusual hail and windstorms in May fruits like cherry, plum, peach and apricot are getting damaged during in recent years.

Impact assessment of global warming in different fruit crops

Aonla (*Emblica officinalis*)

Aonla fruit is valued high among indigenous ayurvedic medicine for balanced diet and sound health. The crop is highly susceptible to frost; its commercialization in frost zones of arid region is now a debatable issue. Fruits of late maturing varieties gets affected by frost and low temperature (<2-3^{0}C). The fruits become whitish in colour, water starts oozing out of them and subsequently they dry and turn black. The plant growth and development after frost injury is poor and particularly in graft scions which leads to no flower /fruit production in next crop season. Under extreme low temperature the whole plant is killed (More and Bhargava, 2008).

Apple (*Malus x domestica*)

Apple is known as The King of temperate fruits. It is mostly grown in temperate region in India and other temperate region in the world. Climate change and variability are serious concerns for apple production. Temperatures of 7ºC and below are effective in meeting the chilling requirements of different temperate fruits including apple (IPCC, 2006). Sufficient chilling hours are not being met with as there is lack of snowfall and rainfall during the winter months. This has resulted in erratic and poor flowering, which is responsible for poor fruit set and low yields (Rai *et al.,* 2015). Decreased volume of snow during winter and rains in winter, spring and summer season has resulted in drought like conditions, which creates moisture stress and trees do not flower properly and normally **(**Chand *et al.,* 2015). At times the temperatures prevailing at the flowering time are fairly high which results in desiccation of pollen and stigma, poor pollen germination and consequently poor pollination and fruit set (Jindal *et al.,* 2000). As a result, the apple growing area is rapidly shifting from lower elevations to higher elevations, and larger area has been reduced unfit for cultivation (Rana *et al.,* 2008).

Banana (*Musa sp*.)

Banana is a plant of the tropics and sub tropics, requiring hot and humid climate. In India, banana is grown in the regions from the humid tropics to humid sub tropics and semi arid tropics. The most suitable climate is the warm moist weather throughout the year without strong winds. The favourable factors determining its distributions are: rainfall in excess of 100 mm per month (Simmonds, 1966) and a temperature range of 10- 40°C with an optimum between 25-30^{0}C and a mean minimum temperature of 15^{0}C. The temperature below 10^{0}C lead to impedance of inflorescence and malformations of bunches. Big challenge for banana cultivation with warmer temperatures is the spread of pests and diseases. The scientists reviewed the potential impact of climate change on the incidence and severity of the most important banana leaf disease, black leaf streak. Preliminary results suggest that the increased temperatures will accelerate disease development. However, rainfall distribution has a much larger impact on disease severity. Since rainfall distribution is less affected by climate change, black leaf streak management will continue to be linked more to rainfall than temperature.

Guava (*Psidium guajava*)

In guava, Red colour development on peel of guava requires cool nights during the fruit maturation. Increase of O.2^{0}C in temperature resulted into dramatic reduction in the areas suitable for development of red colour guava. Increase of O.5^{0}C in temperature will reduce the areas drastically with the suitability probability of more than 97% to a very low level. Based on future climate database, predictions show that area with suitability percentage of less than 70% will be available for red colour guava development. Area suitable for red coloured guava cultivation will be reduced dramatically because the minimum temperature during the coldest month may increase up to 1.9^{0}C whereas, the mean temperature of coldest quarter will be 3.2^{0}C higher than the existing temperature and resulting into less red colour development on guava fruits. (Rajan, 2008).

Mango (*Mangifera indica*)

Mango grows well at temperature as high as 48ºC during the period of fruit development and maturity. Higher temperature during fruit development hastens maturity and improves fruit size and quality. In subtopics, low night temperature (5-10^{0}C) produce synchronous flowering however night temperature of 10-18°C produce a synchronous flowering similar to that in tropics. Climate change may cause abrupt changes in night temperature, which will result into asynchronous flowering in sub tropics and flower bud exposed to cold temperature during night may change into vegetative one under the Warm night conditions. In tropics cool winters followed by rise in temperature may increase poor flowering (Rajan, 2008).

As a result of global warming, flowering trends of mango are considerably altered and directly influence panicle growth. Fruit set and availability of hermaphrodite flowers for pollination may be defined as a function of time taken for panicle growth. Evidence of warmer winters and earlier panicle development, paired with the freeze event pose several problems in mango production. Abrupt temperature rise during the flowering of mango will cause poor fruit set (Rajan, 2008).

Frequent rains during fruit maturation of mango may also affect the development process as well as quality parameters. The heat units required for proper development of fruit and quality may not accumulate up to the critical limit for optimum TSS content development. Rains may also cause leaching of the fruit protective layer, which is instrumental in saving fruits from blackening and postharvest diseases. High temperature coupled with solar radiation may cause scalds on the fruits and thus turning them into unmarketable.

Powdery mildew (*Oidium mangiferae)* a sporadic but serious disease of mango inflorescence and can cause up to 80-90% losses of the crop. Optimal disease development occurs at 10-31°C and 60-90% RH.

Higher humidity (85-90%) and moderate temperatures (maximum temperature of 25-26 degrees C and minimum temperature of 18-20 degrees C) provided favourable condition for the initiation of disease. Lower BSS (4-7 hi day) and lower wind speed (3-5 km/h) were also found to be congenial for disease initiation. Correlations between weather parameters of different lead periods (1, 2, 3 and 4 weeks) with PDI in 39, 47 and 51 weeks revealed that maximum temperature and sunshine hours had negative correlations while minimum temperature, humidity and wind speed had positive correlations (Chata *et al.*, 2006).

Fruits harvested during the humid season are heavily infested but a smaller number of fungal agents were involved; *Colletotrichum gloeosporioides* and secondarily *Phoma mangiferae* played the main role, Thus, climate change is likely to impact the growth and development of mango as well as the pest and disease scenario of the crop (Diedhiou *et al.,* 2007).

Pomegranate (*Punica granatum*)

Pomegranate is one of the favourite table fruits in tropical and subtropical regions. It is considered as a crop of famine area because of its ability to withstand the soil and climatic conditions. The juice is considered to be useful for patients suffering from leprosy. Rind of the fruit is commonly used in dysentery and diarrhoea. The plant can grow best in a temperature range of 10-35^{0}C. An analysis of climate change on pomegranate in arid region has demonstrated that the plant is highly affected by the low temperature. In this crop, the leaves and young shoots are badly affected by frost. Thus, the plant growth and development is highly affected leading to no flower production in next season. On the event of frost injury in the crop, the complete foliage of the plant is dried within 2-3 days and the plant is defoliated. The young shoots also dries killing all vital buds on the twig. Therefore, after leaf shedding, removal of affected twigs is essential for renewed growth of the plant. The recovery of plant after injury with frost is fast and the plant can bear flower and fruit only after 6 months.

Under normal conditions the plant has potential to flower throughout the year. Keeping in view the climatic conditions of the region, the commercial production can be harvested in one of the three seasons viz. ambe, mrig and hasta bahar. In arid conditions, it was generally practiced to take the crop in mirg bahars. This was on account of fact that the flowering and fruit development coincides with the rainy season and fruit mature during winter when the temperature is congenial for development of colour in arils. However, with the advent of frost in this region, the fruits gets hardened, dull skin colour, finally rot and become unmarketable at maturity.

The effect on the fruit is characterized by the initially hardening of fruit due to freezing and frequently it becomes pulpy on account of thawing. The fruit finally become black due to rapid infection of pathogen (More and Bhargava, 2008).

Adaptation strategies for mitigating effect of global warming

I. Breeding strategies
- Development of new genotypes having resistance to high temperature and CO_2 concentrations.
- Marker assisted selection and development of transgenic having resistance to biotic and abiotic resistance.
- Development of genotypes having resistance to heat and drought.
- Crop diversification.

II. Agronomic management strategies
- Development of cropping systems under various agro-climatic conditions.
- Improvement in the irrigation and drainage systems.
- Development of appropriate tillage and intercultural operations.
- Integrated nutrient management.
- Integrated pest management.
- Integrated weed management.
- Development of water harvesting techniques.
- Waste land utilization.
- Development of crop specific models.
- Use of modern technological tools for weather.
- Development of pest and disease forecasting systems.

III. Biotechnological innovative strategies
- Molecular characterization for various traits in relations to biotic and abiotic stress.
- Gene pyramiding against biotic and abiotic stress.
- In vitro conservation of rare and useful species for future use.

CONCLUSIONS

Global warming is inevitably happening and affects many aspect of life on earth. Future studies should attempt to delineate the role of climate change, land use and changes upon the world ecosystems and land cover types (Lehsten *et al.*, 2015). In this way the cumulative, synergetic and multiplicative impacts of multiple driving forces could be addressed in more details allowing sound policy and management recommendations. As an addition step, it seems that tools widely applied in various ecosystems types and species could also be used to address the climatic suitability, climatic stability and climatic niche evolution of fruits (Peterson, 2003; Mazaris *et al.*, 2013; Almpanidou *et al.,* 2016).

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