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Climate change impacts on production of fruit crops

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Abstract: Over the years, environmental changes playing a significant role like occurrence of erratic rain and snowfall, droughts increase in temperature etc resulting in variation in the fruit production in India. Big fluctuation in temperature, rainfall, more frequent occurrence of drought and severe storms are characteristic symptoms of apparent impacts in the area from the global climate change. A significant change in climate at global and national level is certainly impacting horticulture and affecting fruit production and quality. Extreme climates have led to total crop failure in fruit crop production and warmer nights have deteriorated the fruit quality and particular fruit flavor. Storms have lashed seriously and uprooted many fruit crops, e.g., banana, litchi, papaya and mango while chilling injury by frosts destroyed various crops. More frequent draught occurrence also decreased crop yield and in some cases even caused total crop failure. Adaptation to and mitigation of the negative impacts from climate change including political policies, social awareness and technical measures are required to ensure the sustainable development of fruit industry in India. Early technical preparations embraces breeding desirable new varieties of better stresses resistance and high quality produce under field or protected growing conditions.

Key words: Fruits, Climate, Temperature, Management and India

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, condiments, plantation crops and mushrooms. It is estimated that all the horticulture crops put together cover nearly 23 million hectares area with an annual production of 268 million tones. Though, these crops occupy hardly 10% of the cropped area in India with approximately 30.1% contribution in agricultural GDP. India is the second largest producer of fruits after China, with a production of 81.2 million tones of fruits from an area of 6.9 million hectares. A large variety of fruits are grown in India, of which mango, banana, citrus, guava, grape, pineapple and apple are the major ones (Anon., 2014). 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 occurrence of erratic rain and snowfall, droughts increase in temperature etc 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 (Bhargava *et al*., 2011) 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. The consequences of such rapid change are - global warming, change of seasonal pattern, excessive rain, melting of ice cap, flood, rising sea level, drought, etc. leading to extremity of all kinds. Decrease in potential yields is likely to be caused by shortening of the growing period, decrease in water availability and poor vernalization. Vulnerability, rarity and rapid extinction of plant species will be among the other consequences. Plains of India will face similar kind of problems (Lal, and Ahmed, 2014). Nobel Laureate Pachauri said, total agricultural land will shrink and the available land may not remain suitable for the present crops for too long. Farmers have to explore options of changing crops suitable to weather. He also pointed out that climatic changes could lead to major food security issues for a country like India.

Climate change is believed to be a big challenge to the sustainable development of agriculture including the fruit industry in India as well as all over the world. The extent of the impacts of climate change to the fruit industry has become a great concern. However, very little work has been done so far to examine the effects of climate change on fruits in terms of threats, adaptation options and opportunities in new locations. The present paper explores the impacts of climate change to India's fruit industry as well as the necessary adaptation and mitigation measures.

Changing climate in India: India, being a large country, experiences wide fluctuations in climatic conditions with cold winters in the North, tropical climate in South, arid region in West, wet climate in the East, marine climate in coastline and dry continental climate in interior. The IPCC has projected a temperature increase in the range

1.8 to 4.0 ^{0}C by the end of this century. For Indian region, the IPCC has projected 0.5 to 1.2 ^{0}C rises in temperature by 2020, 0.88 to 3.16 ^{0}C by 2050 and 1.56 to 5.44 ^{0}C by 2080, depending of scenario of future development (IPCC 2007). Apart from increase in temperature, climate change is projected to cause variations in rainfall, increase the frequency of extreme events such as heat, cold waves, frost days, drought, floods etc. a significant increase in runoff in many parts of the world including India is projected (IPCC 2007). Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the three main GHGs responsible for climate change. Net carbon dioxide emissions come from energy consumption, i.e. burning of fossil fuels. After fossil fuel use, land use change and forestry, especially deforestation and degradation, are the next largest emitters of carbon dioxide (Baumert *et al*. 2009). Carbon dioxide is responsible for 77% of global warming over a 100 year period and hence the most important GHG. Climate change impacts are likely to vary in different parts of the country. Parts of western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Telangana and Southern Bihar are likely to be more vulnerable in terms extreme events (Mall *et al*., 2006). Overall, the temperature increases are likely to be much higher in winter season than in rainy season. Precipitation is likely to decrease. It is projected that by the end of the 21st rainfall over India will increase by 15-40%, and the mean annual temperature by 3-6 ^{0}C (NATCOM, 2004). The warming is more pronounced over land areas with the maximum increase over northern India. It is also likely that future tropical cyclones will become more intense, with larger peak wind speeds, and heavier precipitation.

Impact of climate change on fruit crops: Fruits growth and development are influenced by different environmental factors (Bindi, *et al*., 2001). During their development, high temperatures can affect photosynthesis, respiration, aqueous relations and membrane stability as well as levels of plant hormones, primary and secondary metabolites. Seed germination can be reduced or even inhibited by high temperatures, depending on the species and stress level (Bewley, 1997).

Mango: Climate and weather play critical roles in the economic success or failure of tropical fruit tree species including commercial mango production. Air temperature and rainfall influence vegetative and phenological phases in mango and are two of the most important factors determining suitability of an area's climate for mango production. Climate-related changes have already brought widespread changes in flowering and fruiting patterns of mango. This is adversely affecting fruit production in some areas. An early flowering under the sub-tropics may result in low fruit set because of several abnormalities caused due to low night temperatures. Late flowering also reduces the fruit set because of pseudo-setting leading to clustering disorder. In addition, high temperatures during panicle development cause quick growth and reduce the number of days when hermaphrodite flowers are available for effective pollination, which may lead to a satisfactory crop. Rising temperatures cause desiccation of pollen and poor pollinator activity resulting into low fruit set (Bhriguvanshi 2010).

Banana: Banana production is highly suitable to both tropical and subtropical environments and it is most limited by high temperatures and drought. Decreases in global banana production are expected in most banana growing areas below 500 masl. These changes might be especially caused by the sensitivity of the crop to high temperatures and drought during the flowering and the fruit filling periods. However, this might bring opportunities for cropping in areas currently limited by low temperatures, although these positive impacts could be reduced by changes in rainfall seasonality, a key driver of banana production. Changes are far less drastic by the 2020s, but these trends are very likely to continue towards the second half and the end of the 21st century (Mall *et al*., 2006).

Citrus: The most limiting factor restricting citrus geographical distribution is low temperatures, frost and freezing damages the fruits and if it persists long enough may kill the tree. Even at mild, non-damaging range, temperatures present major limitations for vegetative growth as well as fruit development and maturation, and temperatures below 13°C during cold periods delay initiation of flowering. In contrast, temperatures above 37°C may cause serious damage to tender fruitlets, and between 44-45°C can slow down fruit growth and cause excessive fruit abscission (Huchche *et al*., 2010).

Papaya: In papaya, higher temperatures have resulted in flower drops in female and hermaphrodite plants as well sex changes in hermaphrodite and male 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 (Saritha, 2012).

Grapes: 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 (Pouget 1981). 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. Kliewer (1977) demonstrated the loss of ovule viability in the varieties Pinot Noir and Carignane at 35°C and 40°C as compared to 25°C. The photosynthesis rate was highest in the temperature range of 20-30°C and the evapotranspiration rate increased with temperature and was highest at 30-35°C (Shiraishi *et al*., 1996). 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 (Buttrose and Hale, 1971).

Pineapple: 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 (Friend, 1981). The coincidence of long days with high temperatures results in irregular flowering, which goes to emphasize the role of temperature.

Pomegranate: Pomegranate grows best in semi-arid climate where cool winter and hot summer prevails. Hot and dry climate during fruit development improves fruit quality. It is fairly winter hardy and also drought tolerant. The plant can grow best in a temperature range of 10-35 ^{0}C. In the water limiting areas, the *Mrig bahar* crop is usually forced, because flowering and fruiting period coincide with rainy season or immediately after rains and crop is taken without much irrigation. Analysis of climate change on pomegranate in arid region has demonstrated that plant is adversely affected by frost. Thus the plant growth and development is highly affected leading to no flower production in next *bahar* (Bhargava and Singh, 2011). On the event of frost injury in the crop, the complete foliage of the plant is dried within 2-3 days and plant is defoliated. The yong shoots also dry up killing all vital buds on the twig. Effect of climate change on pomegranate has been studied by Halilova and Yildiz (2009) and they reported increase in proline accumulation in fruits in hot and dry years.

Ber: The plant is drought hardy and hence survives and gives economic yield in the region. The fruits are nutritious and hence it is also called as the desert apple. Despite the fact that ber is native of arid region, recently the plant is showing some morphological and physiological changes in response to low temperature, or irregular rainfall being experienced by the region. The ber plants can survive a minimum temperature of 4^0 C and can tolerate maximum temperature of 42 ^{0}C. However, various physiological processes get affected at different temperature regimes. For instance, optimum temperature for seed germination is 30 ^{0}C and germination gets inhibited if temperature goes below 25 ^{0}C or above 35 ^{0}C (Bhargava and Singh, 2011). Similarly, fruit setting is drastically gets affected if temperature exceeds 35 ^{0}C. The flowering in this crop is not affected by frost but irregular rainfall has bearing on this process. The flower initiation which normally take place during second week of August to last week of September gets delayed and extends up to October and flower drop increases up to 35- 40%.

Apple: For apple production, the most serious problem is the scab disease and the outbreak of premature leaf fall and infestation of red spider mite. Changes in climate can cause poor harvests or even crop failures. Excess of water and decreased snowfall during winter causes low chilling hours in cropping areas, and this could pose serious threats to apple production worldwide, particularly in India (Singh *et al*., 2010). In India and Nepal, traditional apple cultivation area is moving further up in elevation because of the warmer climate. In addition, climate change and CO_2 are likely to alter important interactions between horticultural plants and pollinators, insects, diseases, and weeds (IPCC, 2007).

Management strategies:

Rainwater conservation and harvesting: These are based on in situ and ex-situ conservation of rain water for recycling to rain fed crops. The arresting of soil loss contributes to reduced carbon losses. Lal (2004) estimates that if water and wind erosion are arrested, it can contribute to 3 to 4.6 Tg year-1 of carbon in India. This is one of the most important strategy not only to control runoff and soil loss. Innovative approaches in ground water sharing can also contribute to equitable distribution of water and reduced energy use in pumping (Pawar *et al*., 2004).

Identifying suitable varieties for new temperature and rainfall regimes: Temperature is probably the most important environmental variable to consider when selecting tropical fruit cultivars for particular sites. The mean temperatures range for optimum growth of most tropical fruits are about 24-30°C (Huchche *et al*., 2010). Monoembryonic mango cultivars tend to be more cold tolerant than polyembryonic cultivars, probably due to their origin of evolution. Amongst citrus species, pomelo (*C. grandis* (L.) Osbeck, *C. maxima Merr.*) is a warm climate crop that requires sufficient water throughout the year with well drained sandy clay loam soils. However, individual species and varieties decrease in susceptibility to low temperatures in the following sequence: grapefruit, sweet orange, mandarin, lemon/lime and trifoliate orange.

Mulching: Mulching is an effective technique for minimization of evaporative losses. Application of externally produced organic mulches affects crop growth by hindering and delaying germination through shading (Kumar, 2012). On the other hand, mulch may enhance soil conditions for plant growth in general so that also weeds are favored. Use of plastic mulches has been successfully demonstrated to increase yield and quality of different fruit crops.

Use of Anti-transpirants: Anti-transpiration coatings have been shown to be effective for maintaining quality through control of water loss (Chundawat, 2000). Anti-transirants are chemicals which when sprayed on plants form a film which increases the diffusion resistance of water from stomata and thus reduces transpiration losses of water. Several chemicals have been successfully used like acropyl in grapes, polycot in banana and kaolinite (3-8%) in different fruit plants. These chemicals are used to reduce temperature on plant parts. Some of these are; phenyl mercuric acetate (PMA), decenyl succinic acid (DSA), atrazine and sodium azide.

Precise Irrigation/Micro-irrigation: Water needs for irrigation can be met, in part, by practicing uniformity of water application-precise irrigation with micro-irrigation-that delivers water from piped mainlines and laterals directly to the root zone frequently and in small amounts, and at rates matched to crop needs. This irrigation strategy has shown to be the best method for saline waters (Mall, *et al*., 2006). The net benefits of micro irrigation improve markedly when such advantages are taken into account. It has been found that up to 81% water saving was observed in lemon compared to flood irrigation with the over 35% increase in yield (Bhansali, 2003). Similarly, ber, grapes and pomegranate recorded 45% saving in water using drip irrigation.

Germplasm/crop selection: There have been reports on the selection of germplasm and cultivars from breeding programmes that will have greater drought stress resistance and hence better production capacity. The fruit crop selected for arid region must be such that its maximum growth period synchronizes with the period of maximum water availability and low vapour pressure deficit in the atmosphere. Ideally the period from flowering to fruiting must be completed well before the onset of summers. Fruits like *ber, custard apple, aonla, pomegranate, phalsa* and *lasora* are suitable for such conditions. Crop like kinnow mandarin can be selected which has tolerance against drought and bear fruits inside well formed canopy (Chundawat, 2000). Some of the fruit varieties are developed in various crops especially for drought stress tolerance namely pomegranate hybrid Ruby, *Annona* hybrid Arka Sahan, fig selections like Deanna and Excel. Dogridge (*vitis champini*) was found promising both for improvement in vigour, yield and quality of seedless grapes as well as tolerance to drought and salinity.

Use of Plant Growth Regulators: Growth regulator applications can also potentially enhance stress resistance, particularly for fruits which are prone to show accelerated ripening or senescence in response to drought stress. Accelerated ripening or senescence is most often mediated by ethylene production in response to the stress. As consequence anti-ethylene products such as aminovinylglycine (AVG) and 1-methylcyclopropene (1-MCP) could be used to mitigate drought stress. IAA and some CKs can antagonize ABA-induced stomatal closure (Singh *et al*., 2001). 100µM abscisic acid (ABA), or 10 µM N^6 benzyladenine (BA) was used to avoid water stress in grafted mango plants.

Use of root stocks: Root stocks play a major role in efficient utilization of natural resources. Root stocks in grape and citrus are essential in improving under abnormal soil conditions. They are helpful in enhancing water use efficiency, biotic and abiotic stress tolerance and adaptation under climate change, scion compatibility, canopy management, canopy architecture, fruit quality and nutrient absorption. Procedures have been standardized to multiply the root stock plants and to raise vineyards in situ on Dogridge (Singh, 2010). Pond apple (*Annona glabra*) is extremely flood tolerant (Mitra, 2013)

Wind Breaks: Before planting an orchard wind break should be provided on the boundary by growing tall trees of Jamun, Arjuna, Poplar, Mulberry and Sisham. These tall trees along with shrubs like Jattikhati, Karonda, etc. can provide an excellent wind break (Saritha, 2012). The roots of the wind break should be separated from the main plantations by digging 2 metres deep trench and 3 metres away from the wind break.

Precision farming: Precision farming calls for efficient managements of resources through location specific hi- tech fruit culture which encompass interventions such as micro-irrigation, fertigation, protected/ green house cultivation, soil and leaf nutrient based fertilizer management, mulching for in-situ moisture conservation (Chandrasekharan, 2009), use of biofertilizers, vermiculture, high-tech mechanization *etc*.

Future strategies for research: (1) Identification and evaluation of genotypes from other regions for frost tolerance. (2) Breeding cultivars of fruit crops tolerant to abiotic stresses of heat, drought, salinity and frost. (3) Development of agro-techniques for overcoming adverse effects of frost. (4) Development of multi-strata farming system models for sustainable crop production under abnormal situation. (5) Crop diversification by introduction of new crop species. (6) Appropriate strategies are to be developed to mitigate the effect of irregular rainfall.

Climate systems may change more rapidly than in the past. Global mean temperatures increased by 0.74 ^{0}C during last 100 years. Industrialized countries are more responsible for threat of climate change. There is no doubt that a change in climatic patterns will affect pollination, fruit size, quality and yield of fruit crops. Increased temperature will influence new disease and pests on fruit crops and more effect on reproductive biology and reduced water supply may affect productivity but adaptive mechanisms like time adjustment and productive use of water may reduce the negative impact. Different management strategies in order to sustain fruit production under impact of climate change and need more time to become effective.

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