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Climate Change: Impact, Mitigation and Adaptation in Fruit Crops

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ABSTRACT

Global climate change and increasing climatic variability are recently considered a huge concern worldwide due to enormous emissions of greenhouse gases to the atmosphere and its more apparent effect on fruit crops because of its perennial nature. The changed climatic parameters affect the crop physiology, biochemistry, floral biology, biotic stresses like disease-pest incidence, etc., and ultimately resulted to the reduction of yield and quality of fruit crops. So, it is big challenge to the scientists of the world. Mitigation is the most important measures to reduce the devastating effect of climate change. Carbon sequestration has the crucial role to mitigate the effect. Fruit crops are highly potential for carbon sequestration. Likewise negative impacts of climate change is also reduce through implementation of adaptation that are relevant, robust, and easily operated by all stakeholders, practitioners, policymakers and scientists.

Key words: *Climate Change, Fruit Crops, Impact, Adaptation, Mitigation*

INTRODUCTION

The Earth's climate, although relatively stable for the past 10,000 years or so and it has always been changing, mainly due to natural causes such as volcanic activity. But since the 1900s more rapid changes have taken place and these are thought to be mainly man-made. Global mean temperatures increased by 0.74˚C during last 100 years and best estimates predict that to increase global annual mean temperatures in the range of 1.8-4˚C during the year 2100; resulted to increase variability in rainfall and enhance frequency of extreme weather events such as heat waves, cold waves, droughts and floods[18]. Climate change is a big threat to human food supply. Around 12 per cent of the world's population is already at risk of hunger, but if temperature rises by only 2 to 3˚C it will increase the people at risk of hunger, potentially by 30-200 million[47]. According to IPCC report it has been projected that; there is a probability of 10–40 % loss in crop production in India by 2080-2100 due to global warming[19]. Food production will be particularly sensitive to climate change, because crop yields depend directly on climatic conditions and could lead to food yields being reduced by as much as a third in the tropics and subtropics[37]. Climate change, particularly increasing temperatures, altered rainfall patterns and climate variability will affect dramatically the productivity of crops and their regional distribution in the next decades with severe impacts on food security.

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Over the past decade or so the fruit growers experienced by the most commonly encountered climatic conditions. Quality and yield of the any crop is only possible through its optimum climatic requirements. The changed climatic parameters affect the crop physiology, biochemistry, floral biology, biotic stresses like disease-pest incidence, etc., and ultimately resulted to the reduction of yield and quality of fruit crops. So, it is a big challenge to the scientists of the world.

IMPACT OF CLIMATE CHANGE IN FRUIT CROPS

A number of studies have provided quantitative assessments of the potential climate change impacts on crop production. The impact of climate change was found from various studies are given as under.

Flowering, fruiting and fruit dropping

Flowering and fruiting are the most important events in all fruit crops which is regulated by climatic condition. Changed climatic parameters disturb the flowering pattern; fruit setting and pollination in many fruit crops through reduce pollinator activity, pollen viability. Rain during flowering wash out the pollen from stigma of flower resulted to poor or no fruit setting. Mango production loss 80-90 % was reported in Gujarat due to unseasonal rain followed heavy dew attack during flowering season; which reduced fruit setting, increased fruit drop at pea stage and also increased heavy incidence of sooty mould and powdery mildew in mango[52]. Likewise, during the year 2008-09 yield of mango was drastically reduce in Gujarat because in this year recorded 2˚C higher temperature during the flower induction period in December seems to have detrimental effect leading to poor flowering and ultimately affecting the crop yield in mango[32]. The real devastating effect was also observed in mango in Gujarat during the year 2009. The temperature was remained detrimental to flowering to fruit setting stage. It was 33 to 36 ^{0}C during flowering stage. The flowering was reduced up to 65-70% in Saurashtra and 85-90% in South Gujarat. The quality of fruit was also going to deteriorates in test and size. The intensity of relative humidity was also found higher resulted to higher infestation of mango hopper and powdery mildew. The state average productivity was reduced up to 2.59 t/ha as compared to 7.0 t/ha[51]. In strawberry, elevated CO_2 and high temperature caused 12% and 35% decrease in fruit yield at low and high nitrogen, respectively. The fewer inflorescences and smaller umbel size during flower induction caused the reduction of fruit yield at elevated CO_2 and high temperature[38]. While in custard apple, the minimum fruit retention (2.68%) recorded during the year 2008. It may be due to higher temperature, lower humidity and higher rain during June-July so; higher rain tends to more dropping of the fruit[53].

Physiological disorder

Due to high temperature several physiological disorder of fruit crop more pronounced e.g. Spongy tissue of mango, fruit cracking, black spot in custard apple, flower and fruit abscission, etc. Air pollution also significantly decreased the yield of many fruit crop and increase of certain physiological disorders like black tip of mango. The mango fruits harvested from clean cultivation showed 15.55 and 18.33 per cent occurrence of spongy tissue under Paria and Ghadoi conditions respectively because of barren soils under clean cultivation showed the mean soil surface temperature to the extent of 52.40°C[21]. While, the rate of transpiration and respiration has an influence on fruit temperature, which in turn has an influence on normal fruit ripening processes and lead to spongy tissue developed[17]. 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[23]. In custard apple maximum black spot (35.63%) on the skin of fruit reported in the year 2009 may be due to high wind speed recorded in the same year[53].

Crop duration

A crop duration or maturity indices the important physiological process in fruit crops which directly affects the fruit quality and yield. The various parameters of climate change also altered the fruit maturation. Production timing of crops will change because of rise in temperature; crops will develop more rapidly and mature earlier[16]. In lowland tropical areas, due to high respiration rates at warm temperatures, citrus fruit mature quickly and do not have sufficient time to accumulate high TSS, and acidity declines rapidly so that the soluble solids/acid ratio increases sharply, and the fruit quickly become insipid and dry[56]. According to The Economic Times, the effects of climate change and global warming are highly apparent with grape harvest starting fully two weeks earlier than ever before[49]. Whereas, in Greece harvest dates of grape was earlier, mainly driven by changes in maximum and minimum temperatures[11]. Likewise in strawberry shift in flowering time in the present climate of Baltic States reported that, typically it takes place between the middle of May and the middle of June (weeks 20-24), while in the past it happened a week or two later (weeks 21-26) and in the future bloom events may be expected as early as the end of April (weeks 18-22)[4].

Shifting of crop belt

Increase in average global temperature would move the existing plant species and varieties to new latitudinal belts with favourable climates. It is, therefore, possible that crops that are used to be productive in one area may no longer be so or the other way round. The resultant of these climate changes are clearly apparent in the shifting of apple cultivation from lower elevations to higher altitudes in India[39].

Disease and pest

Rising atmospheric CO_2 level and climate change may also impact indirectly on crops through effects on pests and disease. Indications suggest that pests, such as aphids[26] and weevil larvae[46], respond positively to elevated CO_2 and change climatic parameters also increased threat of new incursion. While in hot and dry climate reduce the risk of fungal diseases like anthracnose and powdery mildew in mango because Sunlight, low humidity and temperature extremes (below 18°C or greater than 35°C) rapidly inactivate spores[2]. The correlation analysis of weather factors and inflorescence pests of mango showed that morning relative humidity had negatively correlate with hopper population and it showed highly negative correlation with flower bug, thrips/leaf and thrips/inflorescence. The minimum temperature and evening relative humidity had significant negative correlated with flower bug and thrips/inflorescence population, while it showed highly negative correlation with thrips/leaf populations[6].

Irrigation water

Agricultural demand, particularly for irrigation water is considered more sensitive to climate change. A change in field-level climate may alter the need and timing of irrigation. Increased dryness may lead to increased demand, but demand may be reduced if soil moisture content rises at critical times of the year. In fruit crop requirement of annual irrigation will increase, not because of higher evaporation, but the trees develop more fasters during the 12 month period at higher atmospheric CO_2 level. About 80% of reduction in apple yield was estimated due to irrigation water shortage and 20% due to high evaporation rate in apples and reported decrease in chill unit hours in the apple growing areas of Himachal Pradesh[45]. It is projected that most irrigated areas in India would require more water around 2025 and global net irrigation requirements would increase relative to the situation without climate change by 3.5-5 % by 2025, and 6-8 % by 2075[35].

PROJECTED BENEFICIAL IMPACTS OF CLIMATE CHANGE

Increasing temperature and CO_2 level in atmosphere except negative impact they are also benefited to some crops. Like, the photosynthesis rate of C_4 plants was increase as compared to C_3 plant with increase temperature[55]. Whereas, it was observed that C_4 plant species are quickly saturated as CO_2 concentration rises, while in the C_3 species photosynthetic responses continue to rise across a range extending over several hundred ppm CO_2[43]. According to NPCC report, climate change benefitted to temperate region farmers because due to rise in temperature apple belt has moved 30 kms upwards (northward) and the new areas of apple cultivation have appeared in Lahaul & Spitti and upper reaches of Kinnaur district of H.P. which are earlier not suitable for them and in lower elevation region farmers are shifting from apple toward kiwi, pomegranate and vegetable cultivation[28].The floral induction of mango tree is mainly regulated by cool temperatures. Consequently, increasing temperatures would have a negative effect on floral induction. But in regions with particularly cool temperature during flowering, increasing temperatures would have a positive effect on pollen viability and fruit set[8, 33] and it also have a positive effect on mango fruit growth which would be more rapid. In Australia, the estimated duration of mango fruit development decreased by 12-16 days as a consequence of the 1.5˚C increase of winter temperatures so, availability of mango fruit in market was early over the last 45 years[29]. In pomegranate, the hot and dry spell during fruit development increase the proline accumulation in fruit so, climate change may also increase the quality of some fruit crop[15].

MITIGATION

"Climate mitigation means steps to reduce or stop the emission or enhance the sinks of greenhouse gases which are responsible for climate change with the help of conscious practices, which permanently eliminate or reduce the long term risk and hazard of climate change to human life and their properties." The various ways to mitigate climate change through orchard crops are as under.

- Improve efficiency of energy-use by increasing fuel efficiency in agricultural machinery, use wind and solar power, minimal or no tillage, etc.
- Fertilizer, manure and biomass management through reduce use and production of synthetic fertilizers, avoid leaching and volatilization of N from fertilizers during storage and application, use slow-releasing fertilizers, Nitrification inhibitors, etc. Dicyandiamide (DCD) a nitrification inhibitors efficiently mitigating nitrous oxide emission (13-42%) followed by nimin, coated Ca-carbide, neem cake, neem oil and thiosulphate[34]. Whereas, when dicyandiamide applied with organic manures and urea decrease cumulative N_2O emission by 24.18-32.55%[25].
- Soil management for increasing soil carbon (%) by using organic fertilizers, reduced tillage, avoid soil compaction, use biochar, cover crops, intercropping and other cropping system. Maximum soil organic carbon (SOC) stock was recorded under lemon orchard (38.92 t/ha), followed by mango (33.11 t/ha), ber (29.28 t/ha), aonla + aloe (27.74 t/ha), guava (27.70 t/ha), kinnow (21.90 t/ha), phalsa (21.74 t/ha), shahtoot (21.08 t/ha) and the minimum SOC stock was under bael orchards (18.55 t/ha)[13]. Whereas, among different cropping system significantly higher soil organic carbon (1.30%) recorded in coconut + pineapple cropping systems up to 15 cm soil depth[48] and maximum above and below ground carbon density under Rice + Teak agroforestry systems which is 52.47 & 13.12 t/ha, respectively[5]. While, highest carbon tonnes per hectare (tree + intercrop) was sequestered by Agrisilvicultural systems (ASS) system (12.36 to 47.87 t/ha) and most viable agroforestry system on the basis of NPV (Net Present Value), Benefit Cost Ratio (BCR), Equivalent Annual Income (EAI) and compounded revenue was Agri-silvi-horticultural systems (ASH) system followed by Agri-horticultural systems (AHS)[30].

Carbon sequestration

Process of removing carbon from the atmosphere and depositing it in reservoir is known as carbon sequestration or storage of carbon dioxide. In nature there is mainly three way to sequestrated carbon dioxide: 1. Geological sequestration means storage of CO_2 in underground mainly in depleted oil and gas reservoirs or in deep, unminable coal beds. 2.

Ocean sequestration means storage of CO_2 in deep Ocean through solubility and biological by phytoplankton and 3. Terrestrial sequestration means storage of CO_2 in plant biomass and soil through photosynthesis. Fruit orchard have great role in terrestrial carbon sequestration through photosynthesis and stored as carbon in tree biomass such as trunks, foliage, branch, roots and soil and also it provides food and income to the farmers. The trees with thick vegetation, broad and clustered leaves were found to be better CO_2 sequesters[20]. Among the three plantations, the santol plantation has the highest value of carbon sequestration with 203.62 t/ha followed by mango and rambutan[23]. Whereas in case of different pooled area soil recorded maximum carbon sequestration followed by fruit tree, roots, litter and understory. The average equivalent CO_2 in aonla is 18.7 t/ha and in mango is 16.8 t/ha[27] and highest above ground biomass (18.51 t/ha) and carbon stock (8.33 t/ha) in mango plantation[10]. Above ground carbon stock density in mango agrosystem was 3.591 t/ha, while the soil organic carbon was 29.484 t/ha at Northern Ghana[50]. While in guava total biomass, mitigated carbon and carbon stock was 1.43 to 40.54 Mg ha^{-1}, 0.26 to 7.75 Mg $ha^{-1}$and 0.48 to 13.66 Mg ha^{-1}, respectively in 4 to 14 year old tree[41] and in walnut above and below ground carbon sequestration potential was 0.26 t/tree and 0.067 t/tree, respectively[12]. The total above ground biomass carbon stalk per hectare as estimated for aonla was 33.07 kg C/ha, in mango it was 30.6 kg C/ha and in tamarind it was 36.96 kg C/ha and in sapota were 12.86 kg C/ha, in ramphal was 83.1 kg C/ha and for custard apple it was 73.5 kg C/ha[7]. Net carbon sequestered in existing Agroforestry systems over a simulated period of 30 years in Anand, Dahod, Patan and Junagadh districts was found to be 2.70, 6.26, 1.61 and 1.50 Mg C ha^{-1} respectively[42]. The carbon stock and equivalent CO_2 were highest in teak (35.84 t/ha and 131.54 t/ha, respectively) followed by sapota, mango and coconut[3].

ADAPTATION

Adaptation is nothing but to include the actions of adjusting practices, processes, and capital in response to the actuality or threat of climate change, as well as responses in the decision environment, such as changes in social and institutional structures or altered technical options that can affect the potential or capacity for these actions to be realized. There is an immense diversity of agricultural practices because of the range of climate and other environmental variables; cultural, institutional, and economic factors; and their interactions. This means there is a correspondingly large array of possible adaptation options available for marginal change of existing agricultural systems, often variations of existing climate risk management. A crucial component of this approach is the implementation of adaptation assessment frameworks that are relevant, robust, and easily operated by all stakeholders, practitioners, policymakers, and scientists. There are several adaptation measures that in the agricultural sector can undertake to cope with future climate change are as under

1. Crop based adaptation through adapting climate-ready crops or rootstock
2. Based on cropping pattern including cropping systems, intercropping, alternative crops, crop diversification and relocation of crops in alternative areas
3. Adaptation based on cultivars/varieties
    a. Development of tolerant or resistant cultivars/varieties/rootstock against climate change.
    b. Planting different varieties or crop species
4. Modifying crop management practices

a. Modifying date of planting or date of sowing, adjusting cropping season and off seasonal production & marketing of horticultural crops
b. Using sustainable, customized or liquid fertilizer
c. Tillage practices to improve soil drainage, zero tillage, etc
d. Implementing new or improving existing irrigation systems like drip irrigation

e. Improvement in crop residue and weed management and changes in land use management practices
f. Efficient use of resources
g. Adopting new farm techniques, resource conserving technologies (e.g. bagging of fruits, fertigation, etc.). The bagging of mango fruits at marble stage with brown paper and scurting bag gave maximum fruit retension (%), while bagging with newspaper bag gave highest fruit weight and fruit of newspaper and brown paper bags are free from spongy tissue[14]. Bagging of pomegranate fruits with prgmen bags was reducing fruit cracking and sunburn physiological disorders[24].
h. Improved pest and disease management

5. Mulching which conserve the soil moisture, improve soil microclimate, microbial activity and soil health. The plastic mulch was increased yield percentage in papaya (64.24%), mango (45.23%), banana (33.95%), ber (27.06%), guava (25.93%), pineapple (14.63%) and litchi (12.61%) as compared to control[36] and in strawberry maximum runner plant yield observed with the treatment of white-on-black plastic mulch at warmer location kinston and Reidsville, while black plastic mulch at cooler mountain location laurel springs[44].
6. Use of anti-traspirants like chitosane, kaolin, etc. which reflect the heat radiation from plant parts so they reduce the water losses through transpiration and reduce the temperature of fruit and leaf surface and other chemicals. The treatment with anti-traspirant chitosane at 2% gave significantly maximum average finger weight, average hand weight and bunch weight in banana as compared to rest of treatments[1]. Maximum premium grade pomegranate fruits in the treatment with terra alba because it reduces the average fruit and leaf temperature as compared to control[31] and kaolin is an effective treatment for reducing sunburn in pomegranate fruit[9]. Other chemicals like Bordeaux mixture was the best method for reduction of frost damages on grapes grown in moderate cold climate as compared to other frost reduction approaches[54].
7. Wind breaks or shelter belts which modified the microclimate of orchard as well as soil and windbreck also provide shelter for pollinating insects, protect orchard from wind erosion and other natural disaster, etc. The minimum mortality percentage of fruit plants affected by frost was observed in orchards of fruit crops surrounded by wind breaks (2.97 to 30.81%), whereas in the absence of these barrier led to maximum mortality (up to 91.43%)[41].
8. Weather forecasting and crop insurance schemes for farmers and Use of GIS
9. Recycling of waste water and solid wastes in agriculture and use water harvesting technologies

CONCLUSION

Global climate changes are likely to exert pressure on fruit production system and may constrain in attainment of future fruit production targets. These changes are natural but its control in our hand through several mitigation measures which reduce the concentration gases in atmosphere which are responsible for climate change and fruit crops have a great in mitigation of these gases through carbon sequestration by photosynthesis. At present, available adaptation strategies can help to reduce negative impact in short term but to a limited extent. We therefore need to urgently take steps to increase our adaptation capacity by increasing research on adaptation, capacity building and changes in polices and implementation of adaptation assessment frameworks that are relevant, robust, and easily operated by all stakeholders, practitioners, policymakers, and scientists.

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