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Impact of Climate Change on Apple Production in India: A Review

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ABSTRACT

Significant variation in mean state of the climate or in its variability persisting for an extended period (typically decades or longer) is referred as climate change. It may be due to natural internal processes or external forcing or persistent anthropogenic changes in the composition of the atmosphere1. Greenhouse gases like CO_2, CH_4, N_2O, water vapours and ozone re-emit some of solar radiations in the form of short wave radiations to the earth surface and responsible for its warming[2]. If they did not perform this useful function, most of the heat energy would escape, leaving the earth cold (about – 18°C) and unfit to support life[3]. However, since the Industrial Revolution began about 150 years ago, man-made activities have added significant quantities of GHGs to the atmosphere. The atmospheric concentrations of CO_2, CH_4, N_2O have grown by about 31%, 151% and 17%, respectively, between 1750 and 20001. Twenty years ago snowfall was regular phenomenon in high hills of Himachal Pradesh but in the last 20 years, only 2-3 instances of snowfall have been recorded[4]. It has been recorded that the average maximum temperature rose by 0.58oC from the year of 1963 to 2007, whereas, the average minimum temperature rose by 2.75°C[5]. Though, Kullu in northern Himachal Pradesh is well known for apple cultivation, but due to inadequate snowfall and improper chilling hours survivaling affected the cultivation of apple in the region[6]. Chilling affects the flowering and subsequent fruit setting qualitatively as well as quantitatively, [7] have indicated that irregular bearing behavior of Starking Delicious is largely influenced by climatic conditions. The rain and hails during flowering adversely affects the fruit set, whereas, moderate temperature of 20°C with relatively low rains during flowering results in the good fruit set[8]. The plants mortality rate due to drought was higher. The plants mortality rate due to drought was higher. About 80% of reduction in yield was estimated due to irrigation water shortage and 20% due to high evaporation rate in apples[4] reported decrease in chill unit hours in the apple growing areas of Himachal Pradesh. Most of the apple varieties require 1000-1600 hours (at or below 7.2°C) of chill units depending upon the variety[9].

Keywords: Apple, Climate Change, Productivity, Quality.

INTRODUCTION

The world economy has adversely been influenced due to extreme weather events like droughts, floods, cold and heat waves, forest fires, landslides, avalanche, hailstorms, thunder clouds associated with lightning and sea level rise as well as the natural calamities, like earthquakes, tsunami and volcanic eruption may change chemical composition of the atmosphere[10]. The loss of forest cover directly responsible for the erosion of top soil causing floods and droughts thus affecting apple production in the country. Further lack of trees also exacerbates drought in dry years. Therefore changes in surface air temperature and rainfall over a long period of time is known as climate change however year-to-year variations in such parameters is known as climate variability[11].

Climate change underlines the significance of sustainable agricultural production. A stable agricultural ecosystem, can cope up in better way with the stress factors induced by climate change. Climate change and variability are serious concerns for apple production. Climate is an important environmental variable factor affecting the production of fruit crops[12]. The distribution of fruit crops in Himachal Pradesh is influenced mainly by climate rather than any other factor. Farmers' perception on crop-climate interaction underlies the impact of changed climatic conditions on blossoming, fruit set, yield, fruit quality and ecological ramifications [13]. Based on temperature requirements, the fruit trees grown in H.P. can be categorized into subtropical, sub-temperate and temperate regions[14]. Apple is the commercial temperate fruit crop of Himachal Pradesh occupying more than 48 percent of area under fruits. In general cool nights and warm day's conditions are favourale for apple production [7]. The winter must be cold enough to give buds adequate chilling to break winter rest; the growing season must be long enough to mature the crop [15].

Apple crop accounts for about 2.8 % of the total fruit production of the country and ranks sixth in production [16]. Apple production in Himachal Pradesh has increased from 12000 tonnes in 1960-61 to 2 lakh tones in 1975-76[17]. The production of the state crossed the 3 lakh tonnes mark in 1981-82 with an average yield of 10.84 t/ha. The highest ever yield in the state was recorded in 1989-90 (3.94 lakh tonnes) which was nearly touched for the first time in ten year in 1998-99 (3.93 lakh tonnes). Gradual decline in apple productivity from 10.84 t/ha in 1981-82 to only 0.88 t/ha during 1999-2000 with the exception of 1998-99 (6.85 t/ha) and 2013-2014 productivity (6.9t/ha) has been reported by Department of Horticulture, Shimla[16, 18]. Expansion of apple cultivation to marginal areas, monoculture of Delicious varieties, declining standards of orchard management and in the particular fluctuating abnormal climatic conditions are some important factors attributed to declining trend in productivity [7]. In India practically, Himachal Pradesh is located below the apple zone of the world, but apples are commercially grown because the prevailing altitude ranges between 1500-3000 m amsl[19]. The changing climatic conditions such as increase in temperature and decrease in precipitation have influenced apple cultivation in Himachal Pradesh. The decrease in chill units in the normal apple growing zone (1200-1800 amsl) has led to reduction in area under apple orchards[20]. Rising temperatures and changes in weather conditions is affecting apple production and is a matter of serious concern in Himachal Pradesh thus apple farmers have shifted to crops like kiwi and pomegranate[20].

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 scenario[21]. Climate 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[21]. Thus, the climate change is causing the global climatic disruption with immense impact on agriculture. The rise in temperatures over years has adversely affected apple cultivation in both these regions. Twenty years ago snowfall was a regular phenomenon in Kullu town but in the last 20 years, only 2 – 3 instances of snowfall have been recorded. Average maximum temperature of the Kullu valley rose by 0.58^{0}C from the year of 1963 to 2007, whereas the average minimum temperature rose by 2.75^{0}C[4].

Major climate change indicators affecting apple cultivation

The global warm year

1998 was declared the warmest and weather related disaster year of the 20th century. Hurricane havoc in Central America and floods in China, India and Bangladesh, Canada and New England in the U.S suffered heavily due to ice storm in January while Turkey, Argentina and Paraguay with floods were some disasters happened during the year[1]. However huge crop losses were noticed in Maharashtra (India) due to unseasonal and poor rain fall distribution during 1997-98. The 1997/1998 El Nino event affected 110 million people and resulted in the loss of global economy nearly US$ 100 billion. Insurance companies showed that natural weather related catastrophes caused an estimated economic loss of US$960 billion for the period of 1950-1999 [22].

States affected, Crops suffered and Percentage loss

Parts of Jammu, Punjab, Haryana Himachal Pradesh, Bihar, Utter Pradesh, and North Eastern States. Crops that suffered were Apple, Mango, Litchi, Guava, Papaya, Ber, Kinnow, Pineapple, Sapota, Amla, Assam Lemon, Jack Fruit and Peach Boro rice (Assam)Maize in Bihar(early sowing),Gram Mustard10-100% depending upon crop and variety within the crop. Proper selection of fruit species / varieties, windbreaks or shelterbelts, frequent smoking, covering young fruit plants with thatches or plastic shelter, air mixing and weather forewarning were some strategies to minimize the harmful effect of changing climate.

Rise in temperature

The earth has warmed by approximately 0.75 °C since pre-industrial times (from 1906-2005). The years 1995-2006 have been recognized 12 warmest years since 1850. There is over whelming consensus that this is due to emission of green-houses gases. The snow cover in the lower Himalayas is decreasing rapidly[20]. The rise in temperatures over years has adversely affected apple cultivation in both these regions. Twenty years ago snowfall was a regular phenomenon in Kullu town but in the last 20 years, only 2-3 instances of snowfall have been recorded[4].

Ice melting

As the temperature is rising, the glaciers are melting at faster rate and receive less snowfall and the pace of melt at its mouth creates an imbalance thus Himalayan glaciers are declining rapidly due to climate variability. The rate of retreat of the snow of Gangotri glacier demonstrated a sharp rise up to1970s, and then subsequently decline which could be a consequence of the diminishing rate of rise in temperatures[10]. Although the warming processes continued and there was a continuous rise in temperatures since the last quarter of the past century in the Gangotri glacier. However, Samudra Tapu, one of largest glaciers in Chandra Basin in Lahul and Spiti receded by 862 m between 1963 and 2006, at a rate of 18.5 m in a year[28]. The Himalayan glaciers have retreated by 67% in the last decade and retreat further as temperatures increase. This would increase summer river flow and floods over the next few decades, followed by a serious reduction in flows thereafter[10].

Extreme weather events

The increase in phenomena such as cloudbursts has been widely noticed in recent years[10]. Incidence of landslides was perceived to have slightly declined or constant over the time. The floods that occurred in 1947 and 1995, caused enormous loss of both infrastructure and human resources[11].

Increased CO_2 level

Atmospheric concentration of carbon dioxide have been rising, from approximately 315 ppm in 1959 to a current atmospheric average of approximately 385 ppm[57]. Current projection are for concentration to continue to rise to as much 500-1000 by the year 2100[5].

Problems associated with climate change

The fruit production and meteorological data during the past 4 years indicate a significant role of the abnormal climatic factors during flowering and fruit development in lowering apple productivity. Out of four factors of plant environment, moisture, soil, light and temperature, fruit grower can modify two considerably[27]. The orchardist can irrigate or drain the orchard and can fertilize or modify soil structure to some extent if necessary, but light and temperature has to be taken as such. Amongst all the climatic components, temperature seems to be the most crucial factor in apple crop productivity, however, the role of spring frosts, hails, summer droughts and unseasonal spring rain in lowering the productivity and fruit quality cannot be overlooked[17].

Lack of sufficient chilling hours

Temperatures of 7°C and below are effective in meeting the chilling requirements of different temperate fruits including apple[28]. Sufficient chilling hours are not being met with as there is lack of snowfall and rainfall during the winter months especially in the mid hill areas of Himachal Pradesh[29]. This has resulted in erratic and poor flowering, which is responsible for poor fruit set and low yields[30]. The extinct plantations of apple from Rajgarh in Sirmaur and lower areas of Kullu are live examples of impact

of changing climate[31, 4]. It has also been a general experience that in years when the snowfall is less in temperate fruit growing regions and the winters are comparatively warm, chilling requirement of the plants is not met as a result of which bud break is erratic and delayed and the per cent flowering is also reduced and as a consequence the production is considerably reduced.[32]. Such type of effects is only seen at low elevations particularly in apple, where its cultivation has never been a profitable venture. Temperature changes include rise in temperature and also cold waves. Cold waves have shown significant impact on crop production especially in northern India[33].

Lack of sufficient soil moisture

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[34]. 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[35].

Occurrence of spring frosts

Many times the winters remain warm and dry but during spring time the inclement weather prevails and temperatures go fairly low and spring frosts are experienced resulting in frost injury and damage to the flowers and poor fruit set, that results in low retention of fruit and poor resultant yields[7].

Poor pollination

The occurrence of spring frost and low temperature at the time of flowering and fruit setting adversely affects production of fruits[36]. The area's most vulnerable to the influence of low temperature are located between 5,000 to 6,500 ft. elevations where good spring *season with* adequate sunshine promote apple flowering during mid-March to mid-April[17]. However due to the fluctuating temperature during this critical period particularly rains accompanied by low temperature inhibits the transfer of pollen because of restricted bees activity causes washing off of pollen in addition to retarding the pollen tube growth[37]. It has been established that the flowers are killed below -2.2°C and bee activity is completely stopped below 4.4°C[7]. Thus, fluctuating *climat*ic conditions at the time of flowering and fruit setting should not affect apple production directly[37].

Occurrence of hailstorms

Due to wide fluctuation in temperature, hailstorms are also experienced which cause damage to the flowers and developing fruits at various stages of growth and development[38]. Hail also directly damage plants and force them to get into vegetative phase thereby reducing fruit set in the subsequent season Use of anti-hail nets, special system of training like hedgerow, etc in semi dwarf plantations can be very useful[39].

Cold Waves

Cold waves 'Western disturbances' are known to affect agricultural production year after year over the northern and north-eastern regions in India. The intensity and the aerial extent of these disturbances have influenced the quantum of rainfall and snow over these regions. Cold wave has direct influence on cultivation of apple in northern Himalayas[42]

Elevated CO_2

Plants with C_3 photosynthetic metabolism benefited by increased CO_2 concentrations and will be able to accumulate more biomass. Elevated CO_2 will cause positive impacts; which may be nullified by increased temperature and less water availability ultimately decreased production[2].

Yield

Apple productivity in particulars and stone and other fruit in general has shown declining trend of 40-50 per cent in Himachal Pradesh up to 1500 m amsl due to warmer climate and lack of chilling required chilling hours during winter and adequate growth during warmer summers[40]. The apple growing area is rapidly shifting from lower elevations to higher elevations, and larger area have been reduced unfit for cultivation[6].

Quality

High temperature and moisture stress has resulted in increased incidence(s) of sun burn and cracking in apples which has markedly decreased the fruit quality[30]. The anthocyanin development is influenced by high concentration of UV-rays in the

prevailing areas. The high diurnal temperatures, associated with high variations promote colour development and fruit quality in apple[7]. Such climatic conditions are now found only in cold desert areas of Himachal Pradesh, which is known for quality apple production in India[17].

Occurrence of insect pest and disease

Under the changing climate scenario, existing fungal pathogen and viruses may cause more damage to the crop. Ecological ramifications of changes in climatic conditions are urgently needed[41]. Increasing incidence of pest and disease due to climate change comprises a shift in disease ecology and played a vital role in apple production[42]. An increased number of sprays are now required for the routine control of pests[43]. The number of sprays has increased from about 4 per year in the 1970s to about 12 per year today.

Some minor pests may become major pests in future. Added to these, vector population may increase and new pathogens may emerge due to ecological and climatic change[44]. The most glaring recent example is that of European red mite in apple which has appeared in epidemic form in various apple growing region of H.P. Under moisture stress, damage by shot hole borers, wooly apple aphid, San Jose Scale, blossom thrips and premature leaf fall is more prominent[45].

Blossoming and yield

Climatic changes have brought alteration in the pattern of blossoming, bearing and, ultimately the fruit yield. The lack of early cold in December and January adversely affect the chilling requirements. Late cold during April month can delay blossoming and reduce the pollination activity of bees[46]. Also rainfall in this period washed away the pollen in plants. Occurrence of late snow, not only fails to

Effects of Cold waves

States affected	Parts of Jammu, Punjab, Haryana, Himachal Pradesh, Bihar, Uttar Pradesh and North Eastern states.	
Crops suffered	Mango, Litchi, Guava, Papaya, Ber, Kinnow, Pineapple, Sapota, Aonla, Assam Lemon, Jackfruit, Peach, Apricot, Boro rice (Assam), Maize in Bihar (early sowing), Gram and Mustard.	-Fruit size and quality were affected in horticultural crops. -Damage is more in low lying areas. Where cold air settled and remained for long time on ground.
Percentage loss	10-100 per cent depending upon crop and variety within the crop (Mango).	Temperate fruits such as Apple, Plum and Cherry gave higher yield due to extended chilling
How to reduce impact	Proper selection of fruit species/varieties, wind breaks or shelter belts, frequent smoking, covering young fruit plants with thatches or plastic shelter and air mixing.	Weather forwarning.
Effects of Heat wave		
Apple	1. Flowering was early by 15 days. 2. Large scale flower drop due to acute stress, heavy rainfall during second fortnight of April accompanied by short fall in temperature caused poor fruit set. 3. Optimum temperature for fruit blossom and fruit set is 24 ^{o}C while the region experienced above 26 ^{o}C for 17 days.	

replenish soil moisture to the desired degree and but also affects the process of pollination indirectly, by immobilization of bees[47]. Chilling affects the flowering and subsequent fruit setting qualitatively as well as quantitatively[48]. Inadequate chilling has lead to poor flowering and fruit setting. The average minimum temperature during December, January and February, which is the chilling sensitive period, has gone up by 2.27, 2.68 and 3.63^{0}C, respectively. Inclement weather had damaged apple bloom in the lower areas. The rain has washed pollen from flowers, restricted the movement of honeybees, which is crucial for good fruit set[49, 54].

Opportunities

A classical example of Kullu and Lahaul Spiti- Making an opportunity in changing climatic scenario:

Delineation of Areas for Apple Cultivation

Lahaul and Spiti district, which was considered unsuitable for apple cultivation a decade ago, is now witnessing flourishing apple orchards[50]. On an average, every year, 60000 apple saplings (enough to cover 120 hectares) are being planted in Lahaul and Spiti in Himachal Pradesh. This is a new opportunity for farmers of this region due to rising temperature in the valley. The early-planted orchards are now in production stage[51]. The quality of produce is rated the best in the market and almost entire produce is being exported to Gulf and south East Asia region. Lahaul-Spiti has a distinction of using only night soil and FYM in the apple orchards [17].

Diversification in fruit cultivation

With apple production being greatly affected, farmers are steadily moving towards other crop options. Farmers have shifted to cultivation of pomegranate, kiwi and other vegetable crops[6]. Climate change is now know to be a universal phenomena and is to continue. From the past experience, appropriate strategies are needed to be develop in respect of diversification, for sustained and consistent fruit production[19].

Approaches to overcome the effect of climate change in apple

Developing Climate-Resilient apple genotypes: Development of apple cultivars that are tolerant to high temperatures, drought tolerance and water-use efficiency, high tolerance to saline soils and irrigation water. The efforts should also be made to check out strategy for Climate-Proofing though Genomics and Biotechnology.

- Low chilling cultivar – Anna, Mayan, Tamma, Vered, Tropical Beauty, Parlin's Beauty, Schlomit, Michel, Neomi.
- Drought tolerant (rootstocks) – M. 7, M. 9 and M. 111
- Winter hardiness – Antovnovka, McIntosh, Wealthy, Beacon.
- Powdery mildew resistance – White Angle, *Malus* x *robusta*, David, *M* x *zumi*, Calocarpa.
- Late blooming – Konig zuur, Gros bois, Rome beauty, Frost proof, Northern Spy, Spate bluhender.
- Early maturity – Geneva Early, Quinte, Vista Bella.
- Late maturing – Rome Beauty, Braeburn, Granny Smith.
- Collar rot- Northern Spy, Malling Merton series
- Apple rust-
  - •Homozygous resistance- Arkansas Black, McIntosh
  - •Homozygous resistance- Delicious, Winesap, Wolf River
  - •Fully susceptible – Jonathan and Rome Beauty

CONCLUSION

Global warming is inevitably happening and affect many aspect of life on earth. There are many projections how our climate will look like; temperature projections predict an increase from 1, 4 up to 6, 4 °C by the year 2100 while CO_2 concentration might increase to 850 ppm. That will inevitably change apple production among others. In view of these problems, apple orchardist will have to play a significant role in the climate change scenario and proper strategies have to be envisaged for saving apple production and quality. The traditional apple farming is under stress due to changes in climate. Symptoms like earlier blooming and harvest time are already seen. Negative consequences like deprivation of required winter chilling and changed content of bioactive compounds. At mid hills apple

scab and at low hills pest attack on apple crops are considered as the indicators of climate change. The change in land use practices was attributed to climate change and in many areas the land under apple farming was replaced for production of coarse grains, seasonal vegetables and other horticulture species. Development of low chilling cultivars, crops tolerant to high temperature, resistant to pests and diseases, and producing good yield under stress conditions, as well as adoption of hi –tech horticulture and judicious management of land use resources will be the main strategies to meet these challenge.

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