Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 1219-1228
Received: 02-07-2020
Accepted: 20-08-2020

Arundhati
Department of Chemistry,
University Institute of Sciences,
Chandigarh University,
Gharuan, Mohali, Punjab, India

RM Bhagat
Department of Chemistry,
University Institute of Sciences,
Chandigarh University,
Gharuan, Mohali, Punjab, India

Corresponding Author:
Arundhati
Department of Chemistry,
University Institute of Sciences,
Chandigarh University,
Gharuan, Mohali, Punjab, India

Impact of climate change on apples production: World scenario

Arundhati and RM Bhagat

Abstract
Climate change is most important challenge for human advancement in future and the horticulture sector is very sensitive and vulnerable to climate change. Apple cultivation is highly gainful economic activity. This review is mainly the analysis of worldwide situation of apple production, its major climate indicators and the adaption strategy adopted worldwide. Climate is adversely affecting the production of apples in some of the regions of the world like warmer winters which lead to early blossom of fruit trees, can finally lead to regionally dependent increased risks of the occurrence of frost days after apple blossom. In India apple is mostly grown in the states of Jammu &Kashmir, Himachal Pradesh, Uttrakhand and Arunachal Pradesh and these states also are no longer remain unaffected from climate change. There is a dire need to develop adaptive strategies and look for climate resilient apple cultivars.

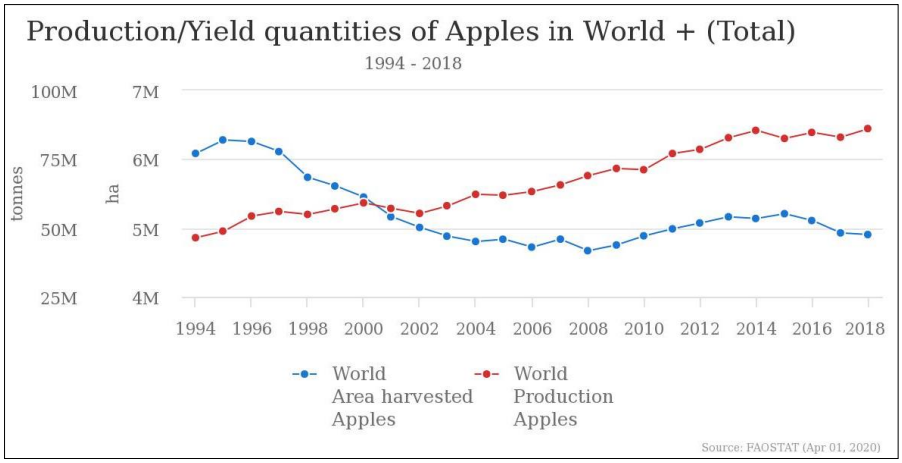
Keywords: Climate change, apple, production, quality

Introduction
Climate change, a universal phenomenon, is a major concern for food and nutritional security of growing population, expected to be 9.5 billion at the end of 2050. Climate change as a whole is a term described as shift in worldwide weather phenomena linked with an increase in global average temperatures, which may be due to external forcing or natural internal processes, or to the anthropogenic changes in the composition of the atmosphere or in land use (Baldos and hertel, 2014) [4]. Earth is an ideal place in our solar system to support life and it's because of its unique environmental conditions i.e water, an oxygen-rich atmosphere and a suitable surface temperature are present on is planet. It has an atmosphere of proper depth and chemical composition. About 29 percent of the solar energy at the top of the atmosphere is reflected back to space by atmospheric particles, clouds, or bright ground surfaces like ice, sea and snow, while the rest reaches the earth, warming the air, oceans and land, maintaining an average surface temperature of about 15°C (NASA Report). In atmosphere, energy is absorbed by the land, seas, mountains, etc., and simultaneously released in the form of infrared waves (Sivaramanan 2015) [41], As the heat makes its way through the atmosphere and back out to space, greenhouse gases absorb much of it, consisting of carbon dioxide, methane, nitrous oxide, water vapor, ozone and a few others. Thus, increased concentration of greenhouse gases leads to increased temperature which in turn has an adverse impact on the world climate, leading to the phenomena known as climate change.
The variations in the climate may impact agriculture/horticulture/livestock/fish and consequently food supply. Directly or indirectly both agricultural as well as horticultural crops are affected by the global climate change. Nowdays people are more concerned about their diet and eating habits. A busy lifestyle and stressful work culture have increased the consumption of fruits and vegetables. Horticulture typically covers four fields of study: post harvest technology (management of produce after harvest), Olericulture (vegetable culture), Floriculture (culture of ornamental crops) and Pomology (fruit culture). Agriculture is an ecological system, manipulated carefully, whose productivity could increase as higher levels of atmospheric CO_2 will allow a higher rate of photosynthesis. Throughout the developing world, rise in the requirement for horticultural products is propelled by the acknowledged health benefits of a diet that is adequate in vegetables, fruits and nuts.
Horticulture is a major component of agriculture in India and has experienced serious threat from climate change in order to provide sustainable income from farm and nutritional security, it is important not only to consider the climate change impacts on different horticultural crops but also to provide measures/ adaptation strategies to mitigate the undesirable impacts of climate change and, if, any, to boost its positive influence. In India evidence of climate change could be clearly depicted by changes like receding snowfall, increased temperature and shifting of temperate fruit belt upward, adversely affecting productivity of apple.

The productivity level has been adversely affected due to increase incidence of insect-pest and diseases (Bhagat *et al.* 2004) [8].

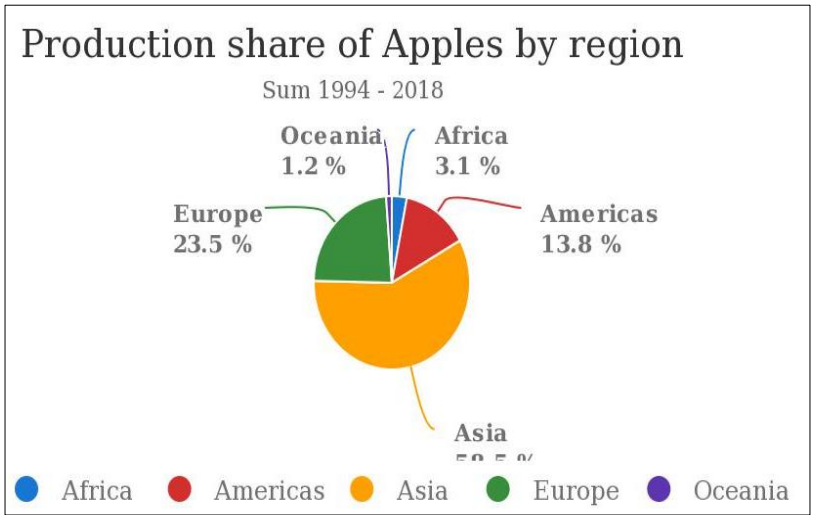
The apple has been cultivated in Asia and Europe from ancient times and it has been considered as the most ubiquitary of temperate fruits. Even was familiar to Greeks and Romans discussed by Theophrastus in the third century B.C. Since that time the apple is found almost in every art of the world. Apple was made to grow in different selected environments as genetic fluctuation has been observed in it. Research efforts are going on to develop new types of apples cultivars that can grow in both colder and warmer regions. For example, it grows in Northern China and Siberia, where winter temperature falls to -40°C, also apples are now grown in Indonesia and Columbia which are near equator where two crops are produced in a single year (Janick 1996) [23].

The leading continents/countries for apple production are presented in Fig 1. Asia ranks number one in terms of production of apples and China and India lead in production, yield and area (fig 1). The production share of some regions is shown in Fig 2.



Source: FAO, 2019

Fig 1: Production and Yield of Apples in world



Source: FAO 2019

Fig 2: Production share of Apples by region

Golden Delicious and Delicious are the two cultivars which are grown extensively in the world (Janick, 1996) [23]. A huge transformation is seen in the apple industry by using golden delicious, which can be used to develop high proportion of new cultivars due to its seedlings, moreover, it is used in breeding successfully. Though Apple is known from ancient times, hence some of its old cultivars still exists as it is vegetative propagated and is a long life tree.

International Scenario

During the 20th century, worldwide in the apple growing regions, there was a variation from -35 to +35^0 C in a day in the range of absolute maximum and minimum temperatures (Jonaitis, 2001) [25]. Further, in the 2nd half of century the large number of absolute minimum and maximum temperature episodes were registered to 58% and 56 %, respectively. Jonaitis (2001) [25], thoroughly examined the fluctuation in 28 vegetative seasons from 1973 to 2000 and found that cycle of emergence lasted for 15 to 35 days and time varies from 0 to 25 days.

Fig 3 shows the country's leading in area harvested, production and yield of apples in 2018 and Table 1 shows the apple exports quantity (FAO, 2019).

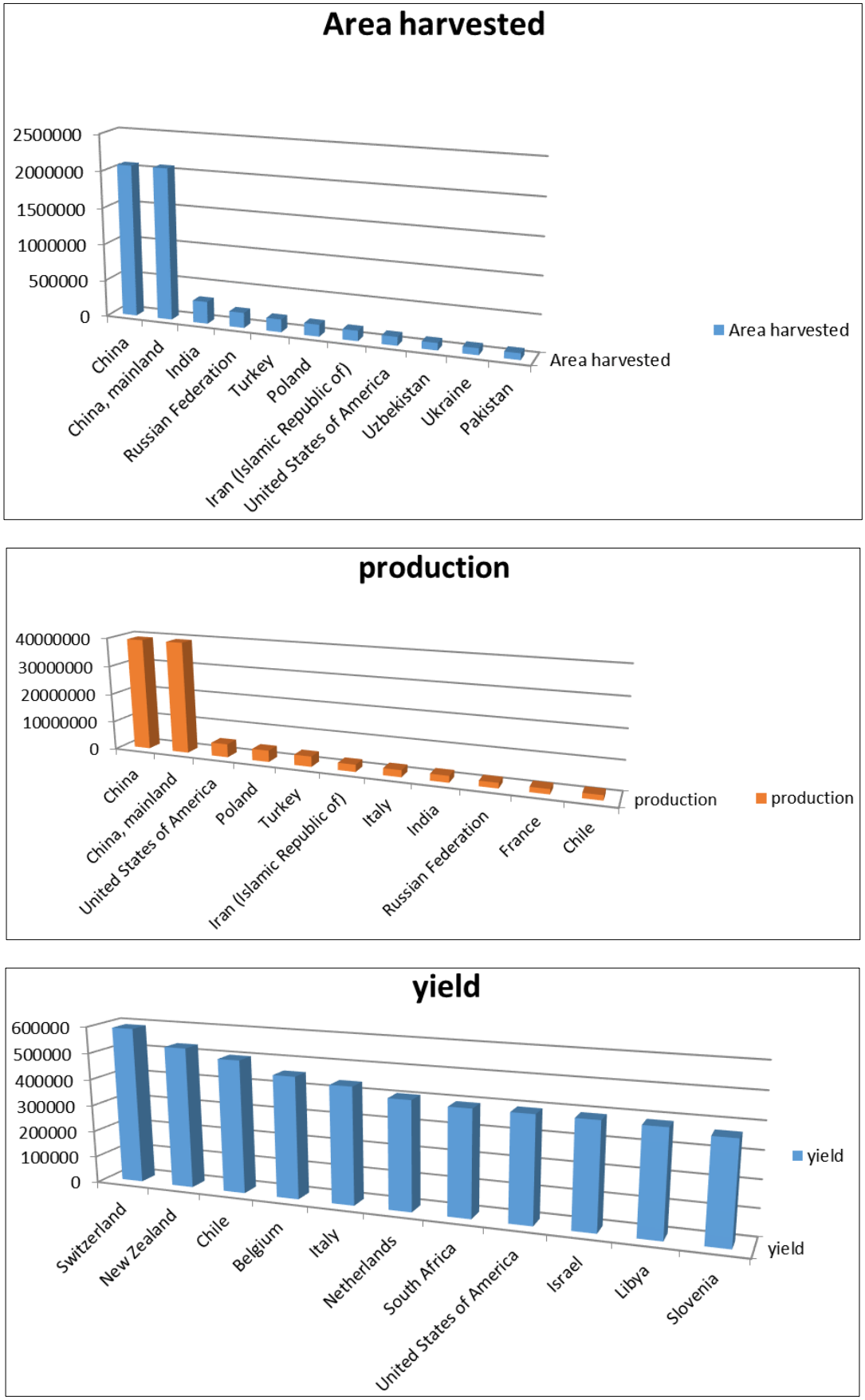


Fig 3: Countries leading in Area, Production and Yield of apples in 2018

Bukovcanova and Mezey (2004) [12] studied the phenology of three apple cultivator namely, spring cultivar Prima, summer cultivar James Grieve Red, and winter cultivar Golden Delicious and the effect of global radiation, daily average temperature, rainfall and average air temperature. It was observed that the phenological phases of all the cultivars were dependent on the global radiation and average daily temperature, and were less dependent on rainfall.

Crepinsek and Kajfez (2004) [17] believed that 1^0C rise in temperature shortened the period of leaf appearance to ripening in apple trees by 2 days, or by 4-5 days with a 3^0C rise. Similar results were obtained for plum trees. However,

for grape vines, 1^0C rise in temperature shortened the period by 1-2 weeks in cultivars with a growth period of 150-200 days and an active temperature sum requirement of 2300-3000^{0}C.

Table 1: Ranking of apple export quantity in the world.

Area	Element	Item	Year	Unit	Value	Ranking
China, mainland	Production	Apples	2017	tonnes	4.14E+07	1
United States of America	Production	Apples	2017	tonnes	5173670	2
Turkey	Production	Apples	2017	tonnes	3032164	3
Poland	Production	Apples	2017	tonnes	2441393	4
India	Production	Apples	2017	tonnes	2265000	5
Iran (Islamic Republic of)	Production	Apples	2017	tonnes	2096749	6
Italy	Production	Apples	2017	tonnes	1921272	7
Chile	Production	Apples	2017	tonnes	1766210	8
France	Production	Apples	2017	tonnes	1710755	9
Russian Federation	Production	Apples	2017	tonnes	1639421	10

Sugiura and Yokozawa (2004) [42] studied the impact of global warming on the production of apple (Malus domestica) and satsuma mandarin (Citrus unshiu). The annual mean temperature was taken as parameter to study the changes in the regions favorable for the cultivation of apple and satsuma mandarin. To calculate the annual mean temperatures the database of Climate Change Mesh Data (Japan) was used, which is derived from four (AOGCM) Atmosphere-Ocean General Circulation Models at 10x10 km mesh. It was observed that favorable regions to cultivate apple and Satsuma mandrin will constantly move northwards. This study showed that some parts of Japan like Hokkaido is suitable for apple cultivation and Central Tohoku is not favorable for it.

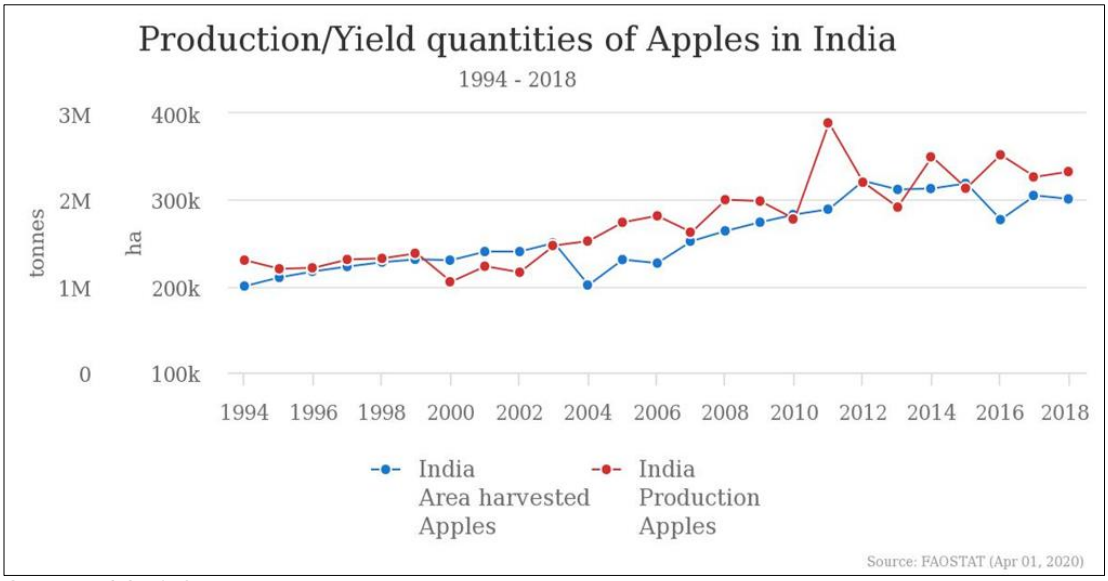
Yubi *et al*. (2005) [49] analyzed the meteorological factors such as sunlight, temperature and precipitation based on the climate data from 1961 to 2000 in 6 countries which belong to Longdong loess plateau in China. The results showed that the precipitation over the Loess Plateau decreased and temperature increased as the global climate turns to warm and dry. It also depict that the region is suitable for planting apricot apple and jujube etc. and is less suitable for pear, peach and further reported that the planting area of suitable and unsuitable fruit tree should be adjusted. The phenomenon of diseases and insect pests of fruit tree was serious because of warming winter.

Wrege *et al*. (2006) studied the impact of increasing air temperatures on the number of chilling hours of State of Rio Grande do Sul, Brazil. As chilling hours of apple is the most important indicator, so it was depicted that increase in few degrees temperature, there would be substantial decrease in the number of chilling hours, leading to a condition of practically not enough chilling hours for growing temperate fruits in Rio Grande do Sul.

Belliveau *et al*. (2007) [7] studied and compared the findings of two studies on farmers' vulnerability to climate and risks in British Columbia's Okanagan Valley between 2002 and 2004. It was observed that various climate and non-climate risks that producers identified as "bad years" and the farm-level adaptations employed to manage the associated risk, implied producers' capacities to adapt to multiple risks and the nature of apple growers' vulnerabilities.

Indian scenario

In India Apple crop ranks sixth in terms of production and covers about 2.8 % of the total fruit production. According to National Horticulture Board, the total area covered under apple was 277.16 thousand ha. (2015-16) and total production in country was 2521.09 thousand MTs (2015-16). Apple production in Himachal Pradesh (major apple growing state in India) has shown an increase from 1158.4 thousands MTs (2001-02) to 2371.0 thousands MTs (2017-2018). The area under apples has increased from 241.8 (000‟HA) in 2001-02 to 306 (000‟HA) in 2017-18, in Himachal Pradesh.



Source: FAO 2019

Fig 4: Production/Yield quantities in India

As per the IPCC, a rise in temperature from 0.5 to 1.2 °C, 0.88 to 3.16°C and 1.56 to 5.44 °C will be seen in 2020, 2050 and 2080, respectively for the Indian region. Due to this Climate change there will be variation in precipitation (rainfall or snowfall) as well as occurrence of extreme weather events like increse in floods, droughts, cold waves, frost days etc. Thus as a whole agriculture is drastically affected by global warming (IPCC, 2018) [22].

Bhardwaj *et al*. (2010) [9] determined the impact of climate varation on apple cultivation in Himachal Pradesh. It was observed that due to rise in maximum temperature (3.4^0C) and minimum temperature (0.97^0C) during winter season in wet regions has impacted apple cultivation adversely in mid altitudinal range of 1500-2000 m amsl.

Singh (2003) [39] reported that the most important single factor responsible for declining apple productivity in Himachal Pradesh is the changing weather pattern. Reduction in annual snowfall and fluctuating temperatures has been seen during flowering period which has adversely affected the apple productivity. The occurrence of hail storms in many areas also contributed to low productivity of apples.

Partap and Partap (2002) [33] studied various problems concerning apple productivity in apple valleys in Hindu-Kush Himalayas and one such problem identified was climate change. It was concluded that temperate fruit belt is moving upward and productivity of apple has been adversely affected by climate change.

Vedwan and Rhoades (2001) [44] studied the approach of farmers to adapt to climate change in the Western Himalayas of India.

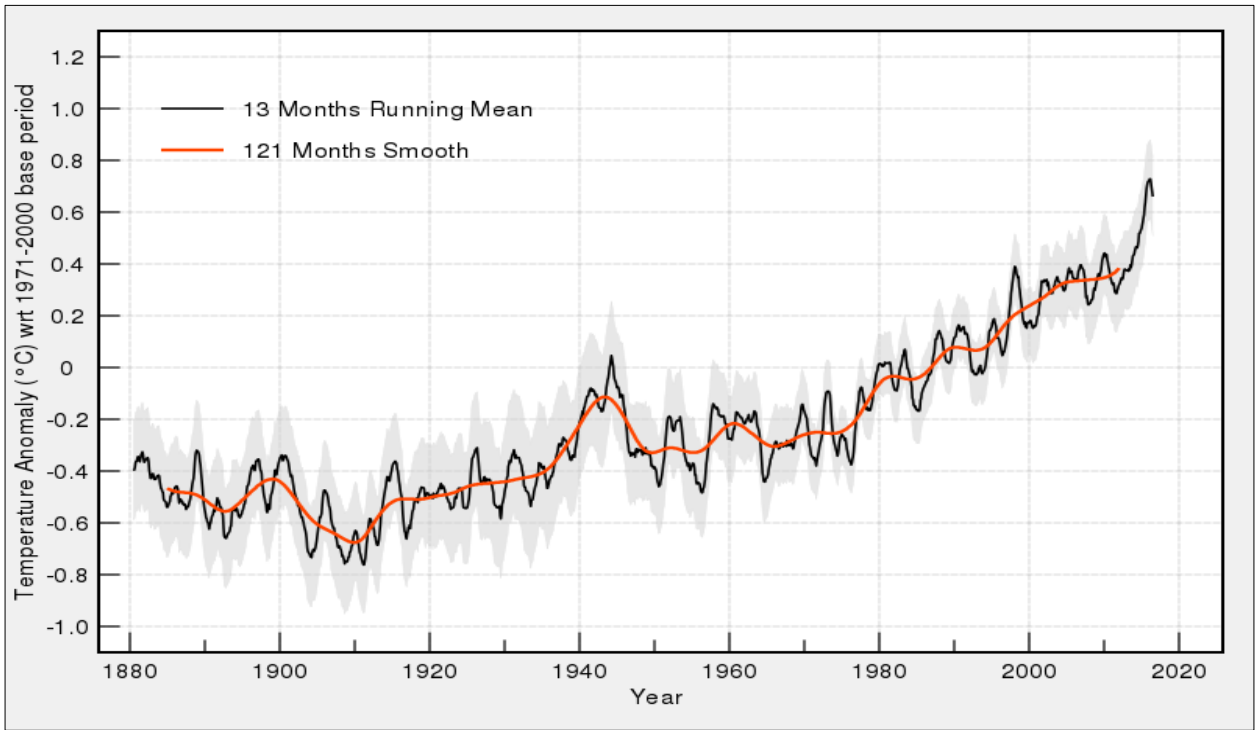
It was observed that effect of climate change could be seen in altereted blossoming, bearing and hence the apple fruit yield. This also affected the fruit quality and degradation in distinct patterns. There is a gap noticed between the flowering periods of male and female trees. The pine plantations in the mid Himalayas have caused a marked change in apple production. Pine trees flower at the same time as apple and produce a lot of pollen which interferes with the pollination process in apple. It was also observed that Kullu district of Himachal Pradesh was once the starting point for apple but now the apple trees population in lower belt of this district is almost vanished.

Awasthi *et al*. (1986) [1] reported that climatic conditions have gradually influenced the irregular behavior of Starking Delicious. He also reported that fruit set is adversely affected by rain and hails occurred during flowering whereas low rain with moderate temperature of 20°C resulted in good fruit set.

Major climate change indicators affecting apple cultivation

1. Rise in temperature

According to a study by NASA's Goddard Institute for Space Studies (GISS) on ongoing temperature, an increase in average global temperature has been observed by about 0.8° Celsius (1.4° Fahrenheit) since 1880 (Fig 5). Since 1975, it was further reported that 2/3rd of warming has occurred at a rate of 0.15-0.20°C roughly per decade. According to this analysis it has been remarked that world apple production has shown decline at its lowest in last eight years in 2018.



Source: NOAA

Fig 5: Rise in temperature from 1880 to 2019

a. The Global Warm Year

According to NASA and the National Oceanic and Atmospheric Administration (NOAA), 2016 and 2018 were declared as the warmest years since 1880. Not every region on the earth experienced similar amount of warming, but weather dynamics have often affected the regional temperatures. Continuous loss of sea ice has been observed in the year 2018 which depicts that warming trends were strongest in the Arctic Region. Furthermore it has also been observed tha the mass loss from the Antarctic and Greenland ice sheets has contributed in the rise of sea level. Some extreme weather events and longer fire seasons are the result of increase in temperature. Italy and Poland which are especially the top apple growers across the European Union

were significantly affected, due to high temperature and severe frost in April 2017. This has also effected the trade in these countries; exports have shown the decline sharply by 45 percent to 820 million tons (USDA report).

b. Ice Melting

Due to gradual increase in temperature, a decline in accumulation rate of glaciers has been observed because of decrease in snowfall and this can create a imbalance at glacier mouth (snout) leading to sudden recession in the Himalayan glaciers Singh, *et al*. (2016) [40]. The mass loss from the Antarctic and Greenland ice sheets have also contributed towards rise in sea level. Glaciologists have gathered enough evidence to report that majority of mountain glaciers and ice caps are retreating and pace of ice melting increased drastically over the last four decades. Moreover, an average of 48 gigatonnes of ice was melted between 1979 and 2001, further this rate propelled to 138 gigatonnes between 2001 and 2017. Mummies which were frozen long back are revealed due to ice melting.

Increased CO_2 Level

Rise in CO_2 is estimated on the basis of fossil fuel burning and about 60% of fossil fuel emissions remains in the air which results in increasing the atmospheric temperature Luthi, D., *et al*. (2008) [28]. According to the NOAA (2018) the global atmospheric carbon dioxide was 407.4 ppm in 2018, which is highest from all years recorded back. Increase in carbon dioxide in the atmosphere may also increase water use efficiency of plants and substantially mitigate/reduce the yield loss due to climate change.

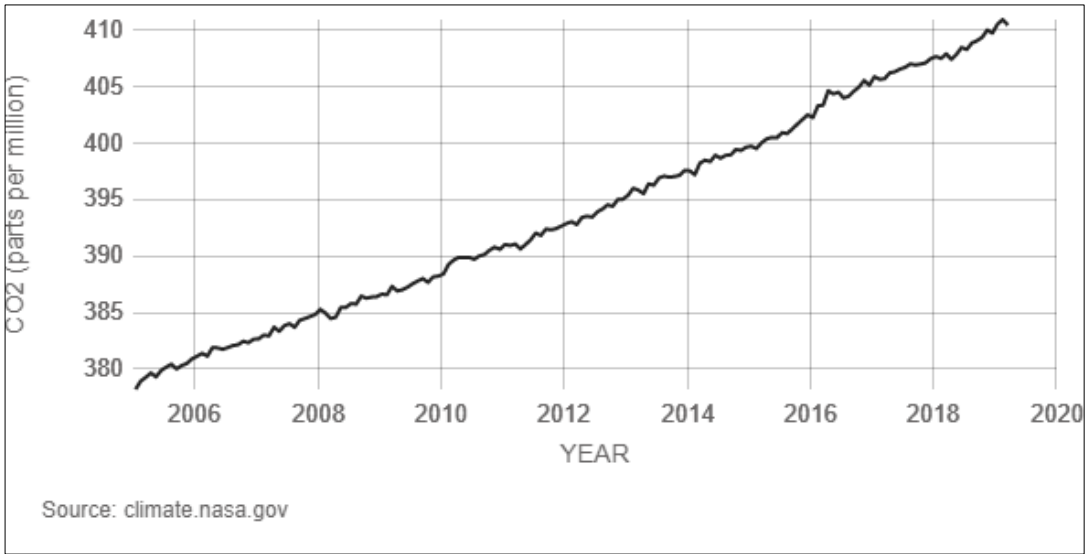


Fig 6: Rise in level of CO_2 from 2006 to 2019

2. Extreme weather events

Long term impacts of global warming have been seen in increased coastal flooding, intense precipitation, heat waves and ecosystem change (Singh, 2016) [40]. Longer fire seasons and some other extreme weather events can also result due to increase in temperature.

Occurrence of Spring Frosts

Recently, it has been observed that winters mostly remain warm and dry. But during the spring season, it can generally be seen that prevailing patterns of weather due to this temperature go fairly low. This may result in spring frosts which damage the flowers and fruits and resultant poor yields and low retention of fruits. This also causes frost injury in the fruits and crops Awasthi, *et al* (2001) [2]. Bruner, *et al* (2018) reported that Europe experience spring frost in the month of April 2016 and 2017, which state a significant risk in the agriculture production, posing considerable damage to agricultural yields

Cold Waves

Western disturbances which normally bring cold waves generally affect agricultural production each year Singh, *et al* (2016) [40]. These waves often affect the fruit size and fruit quality in apple. The aerial extent and intensity of western disturbances have determined the amount of snow and rainfall over these regions. These directly affect the cultivation of apples in the northern Himalayas.

Frequent Hailstorms

Frequent hailstorms are observed in various regions due to fluctuation in temperature, which causes injury to the developing fruits at various stages of its growth and also cause damage to the flowers. In apple orchards hail causes damage to young trees resulting in flower drop. This also leads to reduction of fruit set by forcing the plant to move into the vegetative phase. Hedgrows and anti hail nets are beneficial in the dwarf plantations (Singh, 2016) [40].

Chattopadhyay, *et al*. (2016) [16] witnessed that count of extreme events of very heavy rainfall has increased in India from last 50 years. During pre-monsoon season i.e from March to April generally unseasonal rains and hailstorms are being observed. Due to this extreme fluctuation in weather events, mostly the crops are destroyed in thousands of acres of farmland in many states of India including Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Madhya Pradesh etc which cause huge loss to farmers. Hailstorms also cause extensive damage to standing as well as horticultural crops and matured rabi crops like wheat, mustard, barley, gram etc within a very short time Wani *et al*. (2017) [48].

3. Lack of sufficient chilling hours

Temperate fruits like apple, apricots develop fruiting and vegetative buds in summer and these buds undergo dormancy in winters i.e these crops require a certain period of chilling hours to break the dormancy (Melke 2015) [31]. These fruits mostly require a chilling period of about 1000-1600 hours at

or below 7 degree Celsius. Due to lack of snowfall, rainfall and increase in earth's surface temperature sometime sufficient chilling hours are not met. This affect the flowering and fruit set period because of is affect on pollination and directly causing yield loss. The low chilling varieties or common cultivars of apple mostly require i.e., 600–800 h (0–7.2°C) and 651–1,050 h (< 7.2°C), but a slight increase in temperature can reduce the chilling hours Verma, *et al* (2016). Less chill hours may delay the flowering and cause bud break resulting in deformed buds (Petri & Leite, 2004; Viti *et al*., 2008). It was also highlight to carefully evaluate chill requirements in order to figure out the future production risk and possible shifts in temperate fruit tree growing.

4. Lack of sufficient soil moisture

Summer and spring season have been experiencing drought like conditions due to less snowfall and rains during winters, which builds up the moisture stress and trees do not flower (Singh 2016) [40]. This also result in poor pollen germination, desiccation of pollen and stigma, leading to poor pollination and fruit set.

Zhang *et al*. (2005) [49] stated that tree growth, its development and yield of apple (*Malus domestica* Borkh.) are affected due to emergence of dry soil layer in arid and semi arid regions. It was further stated that low soil moisture usually increases their protoplasmic permealibility and hardens the plants. It also reduces the water content of tissues.

5. Poor pollination

Weather is the most important factor in determining the success or failure of pollination and fruit set (Shaul 2018). Freezing or very low temperature during bloom can injure the flowers and developing fruitlets, which affects the production of apples. Areas which are located at the height of 5000 to 6000 ft Above MSL are most vulnerable as they experience low temperature and receive adequate sunshine, which is beneficial for apple flowering in the month of mid march to Mid April. A slight fluctuation in temperature at this period generally wash the pollen grains and retards the growth of pollen tube as it inhibits the transfer of pollen grains which also restrict the bees activity.

6. Yield

Since apple is economically important tree, hence its yield is associated with financial gains. Economic development of some of the countries depend on the early prediction of yield of various crops (Singh 2016) [40]. Increase in temperature and reduction in chill hours during winters may lead to loss of yield. Climate change also adversely affects the crop physiology, biochemical activity and biotic stress, like disease pest incidence which ultimately results in reduction of yields and quality of fruit crops.

7. Insets pests and diseases

Viruses and fungal pathogen may cause more damage to the crop that even environmental factors, although these vectors of disease are triggered by environmental factors André, *et al*. (2019) [3]. In apple, already identified pathogens and pests cause damage to crop more frequently and this leads to increase in disease and pest incidence. The climate change makes a shift in disease ecology affecting apple production. To control the insect pest and diseases number of sprays are increased and it has increased from 4 per year to 12 per year, resulting in an economic loss o growers (Singh 2016) [40].

Due to climate and ecological change, new pathogens may emerge and vector population may also increase Andre, *et al* (2019) [3]. This can be explained by quoting an example of European red mite in apple, which is observed in many parts of growing regions of Himachal Pradesh, India. Apples are attacked by number of insect pest like San Jose Scale, wooly apple aphid etc.

8. Blossoming and yield

The pattern of blossoming, bearing and fruit yield is altered due to climate change (Singh 2016) [40]. Sometimes when we don't experience early cold in December and January, it adversely affects the chilling requirements and late cold in the month of April, which results in delayed blossoming and reduced pollination activity of bees. Unseasonal rainfall, occurrence of late snow in this period washes away the pollens in plants and fails to replenish soil moisture and affects the process of pollination.

Impact on fruit quality

Incidences like sun burn and cracking in apples are the major indictors of production of low quality apples and this is due to high temperature and moisture stress. Also, Richardson *et al*., (2004) observed that Starch and vitamin C content of kiwifruits is reduced due to exposure to high temperature. Further, citrus fruits which are grown in hot tropical areas also have less amount of Vitamin C in comparison to the areas which have cool nights (Padayatty *et al*., 2003; Njoku *et al*. 2010). Hsiao-hua Pan *et al*. (2007) observed that a slight increase in day and night temperature may reduce the amount of soluble sugars, amino acids, proteins and starch in apple. Increased differences in day and night temperatures late in the season show very little effect on ripening parameters ("Cox's Orange Pippin" and "Elstar" varieties) but flesh firmness is reduced through exposure to higher temperatures during this period (Tromp 1999). High temperatures reduce colour development in grapes. Kentaro Mori *et al*. (2005) observed that for anthocyanin content, night temperatures are more crucial than day temperatures. Comparison of the skin of berries at high and low night temperature showed that anthocyanin content is found more during night temperature and reduced at low night temperature of 15°C (Kentaro Mori *et al*. 2007). It was also observed that this affected the fruit color due to high temperature which leads to development of anthocyanin. Anthocyanin pigments are also found in the skin of wine grapes and malvidin derivatives are the major pigments. Kentaro Mori *et al*. (2007) found that high temperature reduce the synthesis of all pigments in grapes. Tarara *et al*. (2008) studied the effect of berries on high temperature and found that elevated temperature alters the ratio of acylated and non- acylated anthocyanins. It as observed that high concentration of UV rays plays important role in anthocyanin composition of berries. Hsiao-hua Pan *et al*. (2007) observed that the henolic content of the apples is reduced due to increase in day/night temperature (30°C/25°C) Stover and Simmonds (1972) examined that the brighter sunshine and high air temperature (>38° C) cause sunburn damage on exposed fruits and cause choking of bunches. Cracking in apples, cherries and apricot are also seen due to their exposure to high temperature and moisture stress.

Strategies for mitigating the effect of climate change

1. Location-Specific climate adopting smart horticulture

CSH (Climate smart horticulture) is major mitigation tool that the world needs to maintain the food and nutritional security,

besides reducing the emissions, sequester carbon, maintaining the ecosystem services, reduce pressure on forests, produce food and fuel crops. According to (NHB database), horticulture production in India is increasing year by year, e.g. during 2017-18, the production of horticulture crops was 311.71 Million Tones, compared to 269 million MT in 2013. Malhotra, (2014) stated that Climate smart horticulture helps to identify and assess the challenges faced by the farmers in the production and also helps to analyze the favorable technologies for better production of crops.

Climate change is considered as global phenomenon, but its nature, magnitude and extent fluctuate in different regions and locations. Malhotra and Srivastava (2014) stated that climate change is serious issue which can be mitigated by understanding, evaluating and analyzing the status of climate change at regional levels in relation to both annual and perennial horticultural crops and this can be regulated by providing effective solutions through innovation and technology.

Department of Agriculture and cooperation (DAC), Ministry of agriculture, Govt of India promotes the National Horticulture Mission (NHM) in 380 districts in 18 states out of 640 in total including 3 union territories (Census, 2001). This mission is to focus on improving the income of farm including livelihood security and employment generation.

2. Carbon sequestration

Carbon sequestration is generally a process of capturing and storing atmospheric carbon dioxide. There are lots of anecdotal evidence from farmers engaging in practices designed to increase soil carbon in their fields which is termed as regenerative Agriculture (FAO 2020). The worldwide approach to mitigate climate change is to reduce the emission of greenhouse gases and transform the atmospheric carbon to plant biomass and soil organic matter. Through Carbon sequestration some of the mitigation efforts are taken up to reduce the impacts of climate change. A study was conducted in IISC Bangalore to study the mitigation potential of some of the crops and they used PRO COMAP model to study the effect (Malhotra 2017) [30]. The effect of CO_2 on avocado, banana, mango and citrus resulted that increased level of CO_2 significantly increases the rate of photosynthesis (Ravindranath *et al*. 2007; Laxman *et al*. 2010; Schaffer *et al*. 1999). Bickford, (2007), reported that fruiting abilities and prolific flowering of trees increase the removal of carbon from atmosphere and store it in form of cellulose. The table 2 shows different temperate fruit crop potential as C sequesters.

Table 2: Estimates of Standing Biomass per Area (t/ha or Mg/ha), and Calculated CO_2 Equivalents per ha for Perennial Crops

Crops	Total DW (t/ha)	Total CO_2 (t /ha)	Main source of data for calculations
Apple	36	66	Jiménez and Diaz, (2004), Palmer *et al*.(1991)
Peach and Nectarine	40	73	Chalmers and Van Den Ende (1975); Jiménez and Diaz, (2003)
Plum and Prunes	62	114	Kroodsma and Field, 2006
Almonds	100	183	Kroodsma and Field, 2006
Walnut	75	138	Kroodsma and Field, 2006

3. Modelling and climate analogues

Combating climate change require tools like modeling and climate analogues, which helps the farmers to identify the crop traits and varieties that can be needed in particular location Bellard, *et al*. (2012) [6]. It also helps the Breeders and Agronomists to adapt to climate change. Climate modeling generates the future climatic variables like Maximum and minimum temperature, length of growing season, evapotranpsiration, onset of growing season from weather time series. These models are the valuable approach for horticulture as they are used to describe relationships between plant behavior and temperature

Kumar *et al*. (2008) reported that these kind of simulation models are required for production of horticulture crops in India except coconut and potato. Rajan (2008) used the DOMAIN niche model to study the shift in mango growing regions. Innovative methods is the need of an hour to build up the simulation models for important horticultural crops like mango, grape, apple, orange, citrus, litchi, guava, etc., crop simulations models in India are a priority for horticulture crops researchers.

4. Crop Models for Managing Horticulture

Crop management can significantly reduce the yield loss. DSS (Decision Support System) is urgently needed for better management of agriculture at farm and regional level for a sustainable climate resilient crop production (Prasad 2013) [34]. Since a farmer needs answers to several questions related to crop production and marketing crop models are of immense use not only from climate change perspective but also from crop management point of view.

5. GIS and remote sensing

GIS and remote sensing is a tool which we can be used as a mitigation strategy for climate change (Prasad 2013) [34]. This application helps the farmers to know the health of the vegetation. The advance techniques like remote sensing, GPS (Global positioning Systm and GIS (Global information System) are of great use for the assessment, monitoring and management of variations in climate, topograhy, soil and effective use of the land. It is used to forecast the expected crop production, yield, and assessment of crop damage, crop progress, crop identification and identification of pest and disease infestation. Their integrated use provides crucial information to the farmers and governments regarding proper mitigation and immediate action. Brion (2017) [10] stated that this technology is beneficial for government also as it can provide necessary projects to help the farmers.

6. Breeding strategies

New cultivars can be developed which are tolerant to high temperature, produce good yield and are resistant to pest and diseases. The new cultivars will help in mitigating the effect of climate change by producing good yield under stress condition and breeding of low chill varieties have been proved successful (Sharma and Roy, 2010; Hazarika, 2013). Guerriero *et al*. (2010) performed his study in Venturina, Italy to find out the bloom dates of 229 apricots varieties during the warm winter of 2006-07 and concluded that genotypes from northern climates didn't flower while on the other hand genotypes of southern Italy flowered more than usual. A little advancement in the mapping of genetic determinism of chilling are required to propel/boost the breeding process (Griesbach, 2007) [19].

Conclusion

1. China is the leading producer of apple in the world whereas India ranks 6th in apple production, but in productivity India is lagging behind. So its recommended that government should empower economic incentives to the apple farmers to advise them to cultivate apples for commercial purposes rather than for their self consumption
2. Modern technologies should be adopted (climate modeling, Remote sensing) to see the land use management
3. Initiative should be taken to adopt high density varieties of apples to increase the level of productivity
4. More capacity building of boh individuals and institutions to adapt to climate change

References

1. Awasthi RP, Thakur GC, Chauhan PS. Role of meteorological components on flowering time, fruit set and yield of Starking Delicious apple. In: Productivity of temperate fruits Jindal K K and Gautam D R (eds.). 1986, 10-16.
2. Awasthi RP, Verma HS, Sharma RD, Bhardwaj SP, Bhardwaj SV. Causes of low productivity in apple orchards and suggested remedial measures. In: Jindal KK, Gautam DR, editors. Productivity of Temperate Fruits. Solan: Dr. Y.S. Parmar University of Horticulture and Forestry, 2001, 1-8.
3. André Velásquez C, Christian Danve Castroverde M, Sheng Yang He. Plant and pathogen warfare under changing climate conditions. Current Biology. 2019; 28(10).
4. Baldos C, Hertel TW. Global market integration increases likelihood that a future African revolution could increase crop land use and CO_2 emissions., PNAS. 2014; 111(38):13799-13804.
5. Baruah R, Hazarika SM. Modeling Motion Event using QSR. Proceedings of the International Workshop on Spatio-Temporal Dynamics (STeDy 2011), Lisbon, Portugal, 2010.
6. Bellard C, Bertelsmeier C *et al*. Impacts of climate change on the future of biodiversity, NCBI. 2012; 15(4):365-377.
7. Belliveau S, Bradshaw B, Smit B. Comparing apples and grapes: farm-level vulnerability to climate variability and change. Farming in a changing climate agricultural adaptation in Canada. 2007; 43:157-172.
8. Bhagat RM, Kalia V, Sood C, Mool P, Bajaracharya SR. Himachal Pradesh Himalaya – inventory of glacier and glacial lake outburst floods affected by global warming in mountains of Himalayan region. Project report submitted to UNEP, Japan, 2004, 21-24.
9. Bhardwaj SK, Verma KS, Sharma SD. Horticulture production in North-western Himalayan region under changing climatic scenario – a case study. In: Proceedings of 2nd international conference on environmental management held at Hyderabad w.e.f. 25th – 28th October, 2010, 206-213
10. Brion D, Balahadia F. Application of remote sensing and GIS for climate change and agriculture in Philippines., Student Conference on Research and Development (SCOReD), 2017.
11. Bickford D, David L, Sodhi N *et al*. Cryptic species as a window on diversity and conservation, Trends in Ecology. 2006; 22(3):148-55.
12. Bukovcanova, Mezey. Evaluation of selected phenological phases and meterological indicators shifting on agroclimatical regionalization of apples in the Slovak Republic in consequence to global wrming 2004, 1335-2563.
13. Buban T, Faust M. Flower bud induction in apple trees: internal control and differentiation. Horticultural Review. 1982; 4:174-203.
14. Awasthi RP, Verma HS, Sharma RD, Bhardwaj SP, Bhardwaj SV. Causes of low productivity in apple orchards and suggested remedial measures. In: Jindal KK, Gautam DR, editors. Productivity of Temperate Fruits. Solan: Dr. Y.S. Parmar University of Horticulture and Forestry, 2001, 1-8.
15. Camoy JA *et al*. Productivity definition of the chilling requirement reveals underestimation of the impact of climate change on winter chill accumulation. International Journal of Biometeorology, 2018.
16. Chattoadhyay N, Sunitha S, John J, Choudhury VR. Occurrence of hail storms and strategies to minimize its effect on crops. Indian Meteorological Department. 2016, 551.578.7:632.116.3.
17. Crepinsek Z, Kajfez BL. Effect of air temperature increase on changes in temperature sums and length of growing season. Zbornik Referatov 1 Slovenskega Sadjarskega Kongresa Z Mednarodno Udelezbo, Krsko, Slovenia, 24-26 Marec Del, 2004; 2:785-793.
18. Environmental Information System. Climate Change: Himachal Pradesh Perspective. ENVIS Newsletter, 2008; 6(1):3-5.
19. Griesbach R, Ronald B, John H. Gene Expression in the Star Mutation of Petunia × hybrida Vilm. Journal of the American Society for Horticultural Science. American Society for Horticultural Science. 2007; 132(5).
20. Gautam DR, Sharma G, Jindal KK. Fruit setting problem of apple changing climate scenario of North-Western Himalayas of India. Acta Horticulturae. 2004; 662:435-442.
21. Hussein A, Shaban D. Climate change and its impact on the productivity and quality of vegetable crops. Journal of Applied Science Research, 2012.
22. IPCC. Climate Change: Global warming of 1.5°C, Inter-Governmental panel on Climate Change, 2018.
23. Janik J, Moore NJ. A book on Fruit breeding, Tree and Tropical forests, 1996.
24. Jindal KK, Chauhan PS, Mankotia MS. Apple productivity in relation to environmental components. In: Jindal KK, Gautam DR, editors. Productivity of Temperate Fruits. Solan: Dr YS Parmar University of Horticulture and Forestry, 2000, 12-20.
25. Jonaitis V. Some peculiarities of the long-term dynamics of the day's absolute maximum and minimum temperatures and the emergence rate of adult apple ermine moths, 2001.
26. Kajfez BL. Significance of climatic change for fruit production in Slovenia. Zbornik referatov 1 Slovenskega sadjarskega kongresa z mednarodno udelezbo, Krsko, Slovenia, 24-26 marec Del. 2004; 2:771-778.
27. Kentaro M, Sumiko S, Hiroshi G. Decreased anthocyanin biosynthesis in grape berries grown under elevated night temperature condition: Scientia Horticulturae. 2015; 105(3):319-330.
28. Luthi D *et al*. Etheridge, D.M., *et al*. 2010; Vostok ice core data/J.R. Petit *et al*.; NOAA Mauna Loa CO_2 record, 2008.

29. Kriplani RH, Kulkarni A, Sabade SS. Western Himalayan snowcover and Indian monsoon rainfall: a re-examination with INSAT and NCEP/NCAR data. Theory and Application Climatology. 2003; 74(2):115-121.
30. Malhotra S. Horticulture crops and climate change: Review, Indian Journal of Agricultural Sciences. 2017; 87(1):12-22.
31. Melke A. The Physiology of Chilling Temperature Requirements for Dormancy Release and Bud-break in Temperate Fruit Trees Grown at Mild Winter Tropical Climate, Journal of Plant Studies. 2015; 4:2.
32. Naresh KS, Kv B, Rajgoal V, Aggarwal PK. Simulating coconut growth, development and yield with the InfoCrop-coconut model, Tree physiology. 2009; 29(5):75.
33. Partap U, Partap T. Warning signals from the apple valleys of the Hindu Kush-Himalayas. In: Productivity Concerns and Pollination Problems Shreshtha A B M (ed.). Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, 2002, 83-89.
34. Prasad HC. Handbook on Climate-Resilient Horticulture: Adaptation and Mitigation Strategies, Springer, 2013.
35. Reddy RPV, Verghese A, Rajan VV. Potential impact of climate change on honeybees (Apis spp.).
36. Randev AK. To Study the Total Factor Productivity of Apple orchards in Himachal Pradesh-India. MM-I (Phase 1) Final Report submitted to the Nodal Officer, Central Potato Research Institute (ICAR), Shimla, H.P., 2008, 65-6.
37. Shaul Monselise P. Handbook of Fruit Set and Development, 2018.
38. Sugiura T, Yokozawa M. Impact of global warming on environments for apple and Satsuma mandarin production estimated from changes of the annual mean temperature. Journal of the Japanese Society for Horticultural Science. 2004; 73(1):72-78.
39. Singh J. Low productivity trends in the apple growing state of India. Himachal Pradesh: contributing factors. In: Apple farming and livelihoods in the Himalayas Jindal K K (ed.), 2003, 43-58.
40. Singh N, Sharma DP, Chand H. Impact of Climate Change on Apple Production in India: A Review. Curr World Environ, 2016, 11.
41. Sivaraman S. Global Warming and Climate change, causes, impacts and mitigation, 2.1.4889.71, 2015.
42. Sugiura T, Yokozawa M. Impact of global warming on environments for apple and Satsuma mandarin production estimated from changes of the annual mean temperature. Journal of the Japanese Society for Horticultural Science. 2004; 73(1):72-78.
43. Unterberger C, Brunner L, Nabernegg S, Steininger KW, Steiner AK, Stabentheiner E *et al*. Spring frost risk for regional apple production under a warmer climate. PLoS ONE 13(7): e0200201, 2018.
44. Vedwan N, Robert ER. Climate Change in the Western Himalayas of India: a case study of local perception and response. Climate Research. 2001; 19:109-117.
45. Voiland A. UN climate report, NASA Earth Observatory, 2018. https://www.giss.nasa.gov/research/features/201810_unreport/
46. Walkley AJ, Black IA. Estimation of soil organic carbon by chromic acid titration method. Soil Science. 1934; 37:29-38.
47. Verma KS, Mankotia MS, Verma S, Sharma VK. Impact of Climate Change on Mountain Horticulture. In: Singh H., Rao N., Shivashankar K. (eds) Climate-Resilient Horticulture: Adaptation and Mitigation Strategies. Springer, India, 2013.
48. Wani PS, Jakula SV, Singh D. Doubling Farmers' Income, Kisan Mitra, 2017, 160 pp.
49. Yubi Y, Li YB, Zhang MC, Wang W, Zhang XY. Response on climate in Longdong loess plateau to global warming and fruit development impacted. Journal of Nanjing forestry University Natural Sciences. 2005; 29(4):73-77.