



Vulnerability of Temperate Fruit Production to Climate Change: Adaptation and Mitigation Measures: A Review

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ABSTRACT

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). As per United Nations Framework Convention on Climate Change (UNFCCC), change of climate is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time period. The earth's climate, although relatively stable over the past 10,000 years or so, has always been changing, mainly due to natural causes such as volcanic activity. However, since the second half of 20th century more rapid change has taken place, which has been attributed mainly due to human activities. Plausible climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO₂ concentrations. Temperate region of the country, comprising mainly north-west and north east Himalayan region has witnesses a dramatic change in climate over the past 30 years, where adverse effect of climate change on temperate fruit production has been noticed. The carbon dioxide, methane, nitrous oxide, sulphur dioxide, etc. form greenhouse gas (GHG) pools in the atmosphere. Increase in the concentration of these gases is responsible for global climate change. According to Inter Governmental Panel on Climate Change (IPCC), the climate is defined as the average weather, or more rigorously, as the statistical description of the weather in terms of the mean and variability of relevant quantities over periods of several decades (typically three decades as defined by Meteorological Organization). These quantities are most often surface variables such as temperature, precipitation, and wind, but in a wider sense the climate is the description of the state of the climate system. 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.

Key words: Adaptation, Climate change impact, Mitigation, Temperate fruits.

According to IPCC (2007) climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. However, United Nations Framework Convention on Climate Change (UNFCCC), in its article 1, defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. Projection of future climate change reported by IPCC generally considers only the influence on climate of anthropogenic increases in greenhouse gases and other human related factors.

Climate change demonstration

The CO₂ concentration has increased from a pre industrial value of about 280 ppm to 393 ppm in 2010. Similarly, the global atmospheric concentration of methane and nitrous

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oxides and other important GHGs, has also increased considerably. According to the IPCC, this has resulted in warming of the climate system by 0.74°C between 1906 and 2005. In the instrumental recording period of global surface temperature since 1850, out of a total 12 warmest years, 11 years fell in the 1995-2006 period.

The IPCC has projected a temperature increase in the range of 1.8 to 4.0°C by the end of this century. For Indian region (South Asia), the IPCC has projected 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, depending on the scenario of future

development (IPCC, 2007b). Climate change is projected to increase the global temperature, because variation in rainfall increases the frequency of extreme events such as heat, cold wave, frost days, droughts, floods, etc with immense impact on agriculture. The spatio-temporal variation are also projected for such trends.

Global warming

According to IPCC, Global warming is the increase in the average measured temperature of the earth's near-surface air and oceans since the mid-20th century, and its projected continuation.

Impact of Climate Change

Impact of climate change on horticulture

Horticulture, the major component of agriculture in India, is no exemption from the threat of climate change impacts. Indian horticulture is highly diverse and contributes about 30 per cent to national agricultural GDP and contributes substantially farm income, nutritional security and diversification and import revenues. Increased purchasing power is causing demand for quality food products mainly from horticultural crops. Climate change complicates this challenge as it inflicts increased variability in quality and production. In order to provide nutritional security and sustainable farm income, it is imperative not only to understand the impacts of climate change on various horticultural crops but also to provide adaptive strategies/measures to minimize the adverse effects of climate change and to maximize the positive influence of it, if any. Relatively, large amount of information is available on impacts of climate change and climatic variability on field crops as compared to that on horticultural crops.

Impact on temperate fruit crops

Over the last few years, there has been distinct slow growth in production and productivity of temperate fruits and nuts especially in rainfed areas where there is a clear trend of switching over from high chill varieties of fruit crops like apple, walnut, apricot, cherries and almond to growing of low chilling requiring apple, peaches, apricots and other fruit crops like Kiwifruit. as a result of rise in the temperature and decline in overall precipitation, apple in lower altitudes is shifting upwards replacing with low chilling crops like peach and apricots.

Impact on winter chilling

Insufficient winter chill can be severely reduce drop yields and crop quality. When chilling requirements are not completely fulfilled, trees display irregular and temporally spread out flowering, leading to inhomogeneous crop development. This process ultimately results in varying crop sizes and maturity stages at the time of harvest, which can substantially reduce yield amount and value. For species, that rely on overlap between male and female flowering, such as walnuts and pistachios, insufficient chilling can reduce pollination, also leading to reduced crop yields.

If winter chill decline occurs due to climate change, production constraints are likely to exceed those typically reported, because many trees might not even come close to fulfilling their chilling requirements. In such cases, complete crop failure may frequently occur, while early senescence of trees will further reduce their yield potential, rendering many orchard operations uneconomical. Since orchards often remain in production for decades, consideration of future expected winter chill is necessary in times of imminent climatic changes. Without such considerations, many orchards might receive inadequate chilling by the time they reach physiological maturity.

Winter chill, a vital climatic trigger for many tree crops, is likely to decrease in view of climate change. Pace of winter chill will also decline. Winter chill is likely to decrease by more than 50 per cent during this century as global climate warms, making California no longer suitable for growing many fruit and nut crops. Depending on the pace of winter chill decline, the consequences for California's fruit and nut industries could be devastating (Zhang, 2009). The researchers found that in all projected scenarios, the winter chill in California declined substantially over time. Their analysis in the Central Valley, where most of the state's fruit and nut production is located, found that between 1950 and 2000, winter chill had already declined by up to 30 percent in some regions. Researchers projected that winter chill will have declined from the 1950 baseline by as much as 60 per cent by the middle of this century and by up to 80 percent by the end of the century. Insufficient winter chill plays havoc with flowering time, which is particularly critical for trees such as walnuts and pistachios that depend on male and female flowering occurring at the same time to ensure pollination and a normal yield. The researchers project that by the end of the 21st century, the Central Valley might no longer be suitable for growing walnuts, pistachios, peaches, apricots, plums and cherries. The effects will be felt by growers of many crops, especially those who specialize in producing high-chill species and varieties. Almost all tree crops to be affected by these changes, with almonds and pomegranates likely to be impacted the least because they have low winter chill requirements. A minimum number of chill hours (hours during which temperatures drop below 45°F) is required for proper bud setting; too few hours can cause late or irregular bloom, decreasing fruit quality and subsequent marketable yield. California is currently classified as a moderate to high chill-hour region, but chill hours are diminishing in many areas of the state. If temperatures rise to the medium warming range, the number of chill hours in the entire Central Valley is expected to approach a critical threshold for some fruit trees.

Effect on fruit quality

Over the last 40 years, perceptible advances in dates of flowering stages have been observed in apple and pear trees growing in three cropping areas in France and one in Switzerland (Guédona and Legaveb 2008). In addition to the phenological advancement, fruit quality was also affected. Red color plays a very important role when apple

fruits are purchased. Temperature is one of the key factors among those influencing red color development. In general, quality characteristics are worse when discs are cultured at higher temperatures for longer time than those cultured at optimum temperatures or at higher temperatures for less time. Anatomical observation through the cross section of fruit tissues showed that anthocyanin particles were limited only to the cells of the upper layers of the flesh and skin if cultured at higher temperatures. The size of the treated cells, however, was greater than that of untreated cells and it continued to increase with time. Density of red color was greater in the 20 and 25°C treated discs than in those at 30°C (Pan and Shu, 2007). Other quality parameters (such as total soluble solids, soluble sugars, starch, total phenolic compounds, free amino acids, and soluble protein), on the other hand, showed no difference in quality characteristics of all the temperature treatments whether constant, slow increase, rapid increase, transient shifting to high temperatures, shifting to high temperature for different length of period or different day/night temperatures. 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. 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 Jignasa *et al.* (2018). 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 *et al.*, 2016). 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.

Relationships between fruit temperatures and quality at harvest

Sunburn (or solar injury) is the most common temperature-induced disorder reported in fruit. This is because that it is readily observed on the skin. This disorder is less affected by post-harvest conditions, but is worth recording here because it is a consequence of high skin temperatures. Factors which increase the propensity for sunburn are high light intensity, high air temperatures (e.g. apples (Parchomchuk and Meheriuk, 1996) and increased water stress e.g. in cranberries. Another measure of skin damage is reduced photosynthetic activity. This can be measured by reduced chlorophyll fluorescence in avocado and apple. An apple disorder sometimes associated with sun-exposure is water core. In cultivars such as 'Cox's Orange Pippin', it can occur both as an evenly distributed core disorder and in the flesh closer to the skin in regions directly associated with high temperature and light exposure (Ferguson *et al.*, 1999).

Threats from pests, pathogen and diseases

Insect pests proliferate more readily in warmer climates since conditions for growth and multiplication are more favorable compared to cooler conditions. The incidence of other crop diseases like fungal and bacterial infection is also likely to increase if the climate gets warmer. In temperate areas, longer growing seasons will enable insects to complete a greater number of reproductive cycles during the spring, summer and autumn. Warmer winter temperatures may also allow larvae to survive the winter in areas where they are now limited by cold, thus causing greater infestation during the following crop season (Sahai, 2008). California farmers contend with a wide range of crop-damaging pests and pathogens. Continued climate change is likely to alter the abundance and types of many pests, lengthen pests' breeding season and increase pathogen growth rates. For example, as temperatures rise, the climate is expected to become more favorable for the pink bollworm (above), a major cotton pest in southern California. The pink bollworm's geographic range is limited by winter frosts that kill overwintering dormant larvae. As temperatures rise, winter frosts will decrease, greatly increasing the winter survival and subsequent spread of the pest throughout the state (Anonymous, 2006). Temperature is not the only climatic influence on pests. For example, some insects are unable to cope in extreme drought, while others cannot survive in extremely wet conditions. Furthermore, while warming speeds up the lifecycles of many insects, suggesting that pest problems could increase, some insects may grow more slowly as elevated CO₂ levels decrease the protein content of the leaves on which they feed. The climate change i.e. increases in temperature, droughts and CO₂ also affect the three legs of disease triangle. The disease like *Alternaria* leaf spot and scab of apple and gummosis in stone fruits and nuts has become severe. The aphid attack is occurring approximately two weeks earlier for every 1°C increase in average temperature. The red mite and white grub have emerged seriously in almost all crops in temperate areas, likewise the scale insects.

Effect of higher CO₂ and GHGs on fruit yield and quality

Carbon dioxide is important because carbon atoms form the structural skeleton of the plant. A doubling of carbon dioxide levels may increase plant growth by 40-50 per cent though continuous high levels saturate the plant's ability to use carbon dioxide and the benefits decrease with time. Leaves detect and respond rapidly to carbon dioxide concentration. If other factors remain favorable, increased carbon dioxide concentrations will lead to greater rate of photosynthesis in plants. But very high carbon dioxide concentrations may limit plant photosynthesis. Growers of protected horticultural crops are already aware of beneficial effects of artificially raising of concentration of carbon dioxide up to certain stage in greenhouse for increasing crop growth and yield. Higher concentrations of carbohydrates and plant hormones under increased CO₂ level alter the dormancy

status of temperate fruit trees, thereby changing the timing of bud burst and the length of the active growing period. Flowering and fruiting of trees hastened with elevated carbon dioxide levels. The evidence of effect of carbon dioxide concentration on leaf senescence and leaf fall is rather contradictory and may be species dependent but most predictions of the direct effects of carbon dioxide suggested that average yields will increase by about 40-50 per cent with the doubling of carbon dioxide concentration.

Impact of climate change on shift of apple belt in Himachal Pradesh

Rana *et al.* (2008) Three study sites in three apple growing districts viz. Kullu, Shimla and Lahual and Spiti representing different elevation were selected to examine the perceptions of farmers for climate change and to relate the chill units with apple cultivations in the face of climate change. The study site of Kullu district represents 1200-2500m above mean sea level. This elevation zone represents 16.04% of the total geographical area of Himachal Pradesh. The region represents mid hill to high hills and receives snowfall in high hills during winter months. The ambient temperature ranges between 7.9°C and 25.6°C. The elevation above 2200-3250m amsl was represented by the second study site of district Shimla. This elevation zone represents 8.8% of the total geographical area of the state. The area is having mid hills to high hills. Mean annual temperature of the region is 15.4°C. The study site of Lahual and Spiti, represent the northern part of the state, embody Lahual and Spiti, part of Chamba, part of Kullu, Shimla and Kinnaur district. The annual mean temperature of this region is below 14°C.

Socio-economic survey

The socioeconomic surveys were conducted in Kullu, Shimla and Lahual and Spiti regions of Himachal Pradesh to examine how apple farmers in Himachal Pradesh perceive climatic change. Weather data from 1986-2004 was used to measure the accuracy of perceptions of the farmers. Perception of climate change is structured for three valleys (Kullu, Lahual and Spiti and Shimla) with multistage stratified sampling technique by knowledge of crop climate interaction and by differential apple performance outcomes associated with the changed conditions. Local perception of the climate variables to apple production were noticed from forty farmers from each region (19 marginal, 16 small and 5 large farmers from Kullu, whereas, 4 marginal, 9 small and 27 large from Shimla and 9 small, 18 marginal and 13 large in Lahual and Spiti) to know farmers perceptions regarding climate change and its impact on apple cultivation. Perceptions were made on basis of gathering data of two periods (1995 and 2005 years) of snowfall, temperature and rainfall.

Climatic elements trend

The climatic elements trends for Kullu valley and Theog region were worked out using the standard procedure from the past 13 to 23 years weather database. The snow fall trends in past two decades were also calculated for 21 sites

representing different elevations ranging from 1500 to 4000 msl exclusively located in Satluj basins of Himachal Pradesh.

Chill unit calculation models

The Cumulative chill units' requirements of apple for Kullu (Bajaura) and Shimla (CPRI-Shimla) regions were calculated by using Ashcroft *et al.* (1997) method and Utah model (Byrne and Bacon, 1992). The Ashcroft model uses only average temperature of coldest months, whereas, the Utah model uses daily maximum and minimum temperature. Utah model also introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation) as follows:

- 1 hour below 34°F = 0.0 chill unit,
- 1 hour 35-36°F = 0.5 chill units
- 1 hour 37-48°F = 1.0 chill units,
- 1 hour 49-54°F = 0.5 chill units
- 1 hour 55-60°F = 0.0 chill units,
- 1 hour 61-65°F = -0.5 chill units
- 1 hour >65°F = -1.0 chill units.

Impact of changing climate on apple production in Kotkhai area of Shimla district, Himachal Pradesh

Sharma *et al.* (2013) to carry out the study last 9 years (2001-2009) data with respect to meteorological parameters and apple production in the area were recorded. The weather data were recorded at Temperate Horticultural Research Station, Kotkhai and data with respect to apple production of the area was obtained from Directorate of Horticulture, Himachal Pradesh. Keeping in view the various fruit growth and development stages of apple growing season was categorized into four stages viz. dormancy or pre-flowering stage (January- March), flowering, fruit-set and fruit developmental stage (April-June), fruit developmental stage (July-September) and post-harvest stage (October-December). Data with respect to temperature, rainfall and snowfall were averaged accordingly. To work out the variation in weather parameters during different stages of fruit growth and development and fruit production from year to year co-efficient of variation was calculated by simple statistical methods. To find out the relationship between weather parameters and annual apple production correlations were established between weather parameters data during various stages of fruit growth and development and final fruit production.

Belsare *et al.* (2015) 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. Sharma *et al.* (2013). 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. Gunduz *et al.* (2011). 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. 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 Hussein and Shaban (2012).

Study of the consequences of global warming in water dynamics during dormancy phase in temperate zone fruit crops

Nuclear magnetic resonance (NMR) possibly the determination of water properties in biological systems by measuring proton spin density and relaxation time by spectroscopy (Chudek and Hunter, 1997). Magnetic resonance imaging (MRI) technique, a spatially resolved NMR in essence, is cited as an important tool for providing detailed and quantitative information on both water transport and status in intact plants (Van *et al.*, 2009). In addition, it is a non-destructive technique, allowing a continuous developmental analysis that provides morphological and molecular structure information, measurements of biophysical parameters, including diffusion, viscosity, and solute status (Van *et al.*, 2009; Van der Toorn *et al.*, 2000). The long-distance transport of water (sap) plays an important and crucial role in the exchange of nutrients and plant hormones between different organs.

Nishimoto *et al.* (1995) cited the value of 750 chilling hours as the requirement in 'Housui' buds, but the amount of 600 hours below 7.2°C (80% of requirement) brought about the release from end dormancy stage (Yamamoto *et al.*, 2010a). According to Yamamoto (2010), however, abnormalities on floral primordia (partial or total necrosis) and eventual development of new inflorescences, during dormancy progression and at flowering, were observed in all treatments in lateral buds of Japanese pear shoots. These symptoms became severe with prolonged cold deprivation before chilling accumulation (simulation of delayed mild winter, treatment 3) and after consecutive seasons (simulation of permanent global warming situation) (Yamamoto *et al.*, 2010a, b).

Mitigation measures

For overcoming the effects of climate change, some short- and long-term strategies in crop improvement, production, protection and post-harvest management have been suggested which need immediate consideration of policy makers, researchers and extension agencies to ensure sustainable food and nutritional food and nutritional security in the years to come without much further effecting the environment.

Rest breaking

Temperate fruits do not get sufficient chilling in the warmer climate. Associated with this, delayed foliation, protected

bud burst and flowering are some of the major problem necessitating artificial bud break. Earlier, dinitro-o-cresol (DNOC) was in use in many warmer apple growing regions of the world receiving insufficient chilling, but its use now has been discontinued. Now hydrogen cyanide (HCN) has become the replacement for this purpose. It has been very effective in apple and other fruits. In South Africa, mineral oil at 4% plus Dormax at 1 or 2% were sufficient to break dormancy in "Golden Delicious" and "Royal Gala" apples. Thidiazuron (TDZ) has also shown the ability to break dormancy in apple. In general, all the chemicals (DNOC, HC and TDZ) enhanced final vegetative bud burst as compared to control. The treatment compressed and advanced flowering period, but this effect was not evident during warmer summer. The treatments also synchronized flowering between the trees of two cultivars. In a recent study analysis and correlation of the meteorological data from the last 50 years showed two distinct climate phases in Klein-Altendorf, an earlier 30 year period (1958-1987) with a temperature of -0.42°C below the long term, 50-year average of 9.40°C, followed by a 20 year period of a +0.60°C temperature rise (1988 to date). A comparison of the phenological data of phase 2 (1988 to date) with phase 1 (1958-1987) showed 10 days earlier full bloom, 11 days earlier harvest and 4 days earlier leaf drop in the later phase, resulting in a 5 day longer growing period for cultivar 'Golden Delicious' at Klein-Altendorf.

Crop improvement strategies

- Introduction of low chilling cultivars of pome, stone and nut fruits.
- Introduction and collection of gene source from plant and animal kingdom for future improvement.
- Diversification with other high value fruit crops like peach, apricot, walnut, kiwi *etc.* suitable for low chilling areas.
- Development of new genotype which are efficient and high yielding at high temperature and CO₂ concentration.
- Marker assisted selection and development of transgenics having resistance to biotic and biotic stress.

Development of agro-techniques

- Evaluation of the environment impacts of apple production using life cycle assessment (LCA) in order to evaluate alternative agricultural production methods that may reduce environmental impacts. This requires assessment tools that measure the consequences of changing systems.
- To develop a set of high resolution daily based climate change scenarios, suitable for analysis of agricultural extreme events.
- To identify climatic thresh-hold having severe impacts on yield, quality and environment for representative crops and to assess the risks that these thresh-holds will be exceeded under climate change.
- To analyze extreme weather impacts on reproductive and vegetative crop yields, using crop simulation models.
- To identify knowledge gaps on physiological sensitivities, potential pest, disease and weed threats linked to extreme

weather and to propose approaches to reduce the impact of extreme weather events.

- Identify key inputs/ outputs associated with crops production and determine their environmental impact.

Plant Protection strategies

- Strengthen surveillance of pest and diseases.
- Study the pattern of increasing climatic variability and observe the change that could lead to rapid movement of pathogens and insect pests.
- 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).

Post harvest management strategies

- Development of cost effective storage techniques.
- Development of varieties having long shelf life.
- Studies on mitigation of post-harvest spoilage.

Future scenarios

- Climatic effects such as higher temperatures and changes in rainfall and soil moisture could either enhance or negate the potentially beneficial effects of enhanced atmospheric CO₂ on crop physiology. In this changing scenario water stress will be a critical feature of climate change and global warming. The predictable response to this eventuality is to develop crop varieties with greater drought tolerance, those that can withstand moisture stress (Sahai, 2008).
- As there is meager information on the response to elevated temperature on the temperate and tropical fruit trees in India, therefore more studies in terms of phenology, flowering, chilling requirement, pollen germination, fruit set, yield and fruit quality *etc.* needs to be undertaken with short and long term goals.
- Weeds, insect pests and diseases will also be benefited from warming and higher carbon dioxide concentration, increasing stress on crop plants and requiring more attention to pest and weed control.
- Fruit and nut industry will need to develop new tree cultivars with reduced chilling requirements and new management strategies for breaking dormancy in years of insufficient winter chill.
- It is very important to continue plant monitoring in the future so that we remain prepared for the impacts of climate change on agriculture and horticulture (Chmielewski *et al.*, 2004).
- Farm-level adjustments may include the introduction of very early or late maturing crop varieties to beat the vulnerable period. Changing varieties and crop cycles, adjusting the timing of field operations and conserving soil moisture through appropriate tillage methods are other steps to mitigate the effects of climate change (Sahai, 2008).
- Adaptations are required in all sectors. Water resource management, expanding irrigation, food production practices, drought resistant varieties, soil and water conservation, mixed cropping, forest management, anticipatory planting,

biodiversity conservation and fire protection *etc* (Anonymous, 2008).

- We must work for improving our confidence in predictions of crop production under elevated CO₂ and climate change conditions. This would require continuous evaluation of models with existing field experiment data, increased focus on limiting factors (such as pest, weeds and disease) and attention to temporal and spatial scaling issues (Tubiello and Ewert, 2002).
- Obtained results also show that it is equally necessary to develop phenological models in order to estimate the impact of climate change on plant development in different regions of the world. Therefore, in the future more efforts are necessary to estimate the impact of temperature rise on fruit trees, horticultural plants and agricultural crops (Chmielewski *et al.* 2004).

CONCLUSION

The expected climate change in this century will be probably much larger than those observed during the 20th century. Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields. Extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth. The dependence of current phenological patterns on high inter annual and spatial variability suggests that plant species may suffer maximum due to phenological deviations caused by climate change. Detailed life-history studies, including phenology, breeding system, pollination, fruit and seed set, dispersal mechanisms and seed germination, could provide valuable clues about the effect of projected climate changes. Rare and endangered species are important to be considered in the context of sensitivity analysis of global climate change, particularly because many of such species are already facing reproductive stress. Opportunities for expansion of fruit crops such as (wine grapes, almonds, table grapes, oranges, walnuts and avocados) into cooler regions were identified, but this adaptation would require substantial investments and may be limited by non-climatic constraints. Given the long time scales for growth and production of orchards and vineyards (about 30 years), climate change should be an important factor in selecting perennial varieties and deciding whether and where perennials should be planted. Microbial plant pathogens are less likely to be adversely affected by increased CO₂, O₃ and UV-B than are their corresponding host plants and hence changes of host plants mainly trigger any expectable alteration of disease incidence. There emerge two opposing scenarios for occurrence and incidence of plant diseases, with one based on growth stimulation by elevated CO₂ and the other on adverse effects of O₃ and UV-B (Manning and Tiedemann, 1995). Climate change impacts are to be looked not in isolation but in conjunction with all the aspects of agriculture and allied services. The effects of climate change on temperate

horticulture sector are still uncertain. However, in the light of possible global warming researchers should give more emphasis on development of heat and drought resistance crops where crop architecture and physiology may be genetically altered to adapt to warmer environmental conditions besides developing such technologies which mitigate and make full use of the effects of changing climate.

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