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Impact of climate change on productivity and quality of temperate fruits and its management strategies

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ABSTRACT

The entire temperate Himalayan region extending from Jammu and Kashmir to Arunachal Pradesh in India has a unique and fragile eco-system, where the very sustenance and livelihood to more than half of the population are directly or indirectly dependent on horticulture or agriculture and draws about 60 percent of its Gross Domestic Product (GDP) from the surrounding ecological resources. The temperate climate offers tremendous opportunities to produce high quality fruits like apple, peach, plum, almonds, apricot, walnut etc. There has been a marked growth in area and production of these crops but the productivity has remained low and made no significant advancement as compared to other advanced countries. The low productivity is a result of number of factors such as environmental, physiological and biological but the environmental or fast climatic changes are playing a significant role in the form of droughts, erratic rains or snowfall, increase temperature besides change, depleting of glacier resources, change in the pattern of seasons etc. The IMD monitoring reveals that temperatures are increasing in temperate and sub temperate areas by 0.05 ^{0}C/ year but the low warming scenario less than 1^{0}C is unlikely to effect the vernalisation of high-chill fruits (Apple, walnut, apricot, almond, cherry varieties) but if warming scenario exceeding 1.5 ^{0}C would certainly expect the dormancy or chilling requirement of both stone and pome-fruits. Because of rise in the temperature and decline in overall precipitation apple in lower attitudes is shifting upwards replacing with low chilling crops like peach and apricots. The effects of climate change on temperate horticulture in this region have shown certain changes and there is urgent need to 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 mitigates and makes full use of the effects of changing climate.

Keywords: Climate change, temperate fruit, production, strategies

1. INTRODUCTION

The North Western Himalayas have a unique and fragile eco-system, where people are heavily dependent on the natural environment for their sustainance and livelihood and draw about 60 per cent of Gross Domestic Product (GDP) from agri-horticultural system. The climate in this region temperate type mainly characterized by extreme cool winters and mild summers. It offers tremendous opportunity to produce high quality horticulture crops like apple, pear, peach, plum, almond, apricot, walnut and off-season vegetable, and ornamental crops. These crops covers an area of more than 466 thousand hectares and produces fruits of approximately 30 lakh tones (Anonymous, 2017). After independence there has been seen marked growth in area and production of these crops but on the other hand productivity has left far behind as compared to advanced countries. The low productivity is mainly attributed to several factors including environmental, physiological and biological. Climate change is a change of climate over comparable period of time resulting directly or indirectly due to human activity that alters the composition of the global atmosphere. The global mean temperature of the earth's surface has elevated by about 0.74°C (IPCC, 2007) over last hundred years. In the past millennium, 1990's has been the warmest decade and 1998 was the warmest year (Mann *et al*., 1999). 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 for Indian region depending on future development scenario. Climate change is expected to cause variations in rainfall, increase the frequency of extreme events like as heat, cold waves, frost days, droughts and floods etc. The rise in temperature is attributed to alarming increase in the atmospheric concentration of greenhouse gases viz., CO_2, CH_4, N_2O and chlorofluorocarbons mainly due to accelerated pace of industrialization. The expected carbon dioxide concentration in 2100 is estimated to be double than the one observed in the pre-industrial era. With global temperature expected to rise by about 6 °C by the end of the 21st century compared to pre-industrial levels (IPCC, 2007), it is highly unlikely that this agro climatic system will remain stable. Climate change is affecting the temperate agroecosystem in number of ways like shifting of growing season, changes in the length of growth period and altered life cycles of the pollinators resulting in lack of synchronicity with the flowering time of the fruit trees. Vulnerability, rarity and rapid extinction of many temperate fruit species will be among the other consequences of climate change. Increase in temperature severely impacts quantity and quality of flowers, flower drop consequently reducing the fruiting potential and productivity. It may cause loss of vigour, fruit bearing ability, reduction in size of fruits, less juice content, low colour, reduced shelf-life, changes in flavor, nutritional and antioxidant characteristics resulting in the low production and poor quality fruit crops. Higher evapotranspiration rates could lower the water reservoir in soils causing water stress in the plants during dry seasons. The water stress not only reduces crop productivity but also tends to accelerate fruit ripening (Henson, 2008). Rising temperature results in the increased rate of insect, pest and disease infestation. The insects and pests that were latent before climate change can now become a serious threat. Climate change therefore seriously impacts the fruit production potential in temperate fruit crops.

II GROWTH IN AREA, PRODUCTION AND PRODUCTIVITY OF TEMPERATE FRUIT CROPS IN INDIA

There has been a tremendous growth in area, production and productivity of different temperate fruit crops grown in India. The area of apple, pear, peach, plum, apricot, cherry and walnut has increased from 0.45, 0.06, 0.10, 0.03, 0.03, 0.01 and 0.14 lakh ha to 3.14, 0.51, 0.41, 0.31, 0.05, 0.04 and 0.31 lakh ha, respectively from 1961-2016. The production of these crops has grown from 1.85, 0.33, 0.43, 0.11, 0.08, 0.03 and 0.12 lakh tones to 28.72, 3.99, 2.88, 2.62, 0.15, 0.11 and 0.33 lakh tones, respectively. Similarly the productivity of these temperate fruit crops has risen from 4.16, 5.41, 4.30, 3.67, 2.76, 2.50 and 0.86 lakh tones to 9.15, 7.82, 7.06, 8.34, 2.81, 3.08 and 1.06 lakh tones, respectively (FAOSTAT and Anonymous, 2017).

III IMPACT OF CLIMATE CHANGE ON TEMPERATE FRUITS IN DIFFERENT PARTS OF INDIA

The IMD monitoring reveals that temperatures are increasing in both Jammu region and Kashmir valley, with significant increase in maximum temperature of 0.05^0 Celsius per year. The average mean temperature in Kashmir has risen by 1.45° Celsius in last 28 years while in Jammu region, it has increased by the rise is 2.32° Celsius (Ahmed and Lal, 2015).

As a result of rise in temperature and decline in rainfall, the apricot and cherries are fast disappearing from some areas of Kashmir Valley. Due to general rise temperature and less availability of water, the yield and quality of apples in valley and mid temperate region of Jammu are fast deteriorating. Over the last few years, there has been distinct slow growth in production and productivity in rain-fed Kashmir's Karewas areas. Due to unusual hailstorms and windstorms in summer fruits like cherry, apple, plum, peach and apricot are getting damaged heavily (Choudhary *et al*., 2015).

In recent years there marked change in the pattern of snowfall in Kashmir which is effecting all the pome and stone fruits. It has been observed that the snowfall and flowering in some years is coinciding leading to great loss in quantity and quality of fruits. Due to shortage of water for agronomic crops like rice shift has been recorded from agronomic crops to temperate fruits and nut in J&K as fruit crops are more remunerative as compared to agronomic crops. In Himachal Pradesh, the study examines the impact of climate change in recent years on apple indicated that there is a general decline in the productivity of apple. It is evident from the data that temperature in apple growing regions of Himachal Pradesh showed increasing trends whereas precipitation decreased over years. The accumulation of cumulative chill units showed a decreasing trend of the order of 6.385 chill units (CU) decreased per year from 1985-2014 in Kullu district of Himachal Pradesh. The decrease in chill units may be due to the overall increasing trend (0.027 ^{0}C per year) of average temperature over the period. The productivity of apple crop in the Kullu district during the last decade (2005-2014) showed a decreasing trend of the order of 0.183 tons/ha /year. This indicates that the climatic conditions particularly temperature approaching towards unfavorable for the apple production in the Kullu valley of Himachal Pradesh in the recent years. This may lead to shift in apple belt to higher altitude (Chand *et al*., 2016). In Uttarakhand the area under apple cultivation has drastically been reduced. It might be due to less rainfall and higher temperature in winter. It is causing major problem of chilling requirement which is very important to meet for higher and quality production of apple.

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Table 1: Changes in temperature and precipitation *vis-a-vis* apple acreage in Himalayan States during 1980 – 2010.

State	Period	Avg. Annual Temp. (^oC)	Rise in Temperature (^oC) (1980-2008)	Precipitation (mm)	Area (ooo ha)	Approx. new area covered under higher elevations
J & K	1980-85	13.01		726	63.09	-
Ladakh	1986-90	13.58		817	66.85	-
	1991-95	13.12	1.45-2.32 0.5-1 (S) (W)	784	71.33	-
	1996-2000	13.91		585	82.18	6510
	2001-2005	14.46		682	96.34	8496
	2006-2008	13.32		763	138.19	25110
	2001-2002	-		Reduced	0.609	-
	2009-2010	-		(1973-2008)	0.836	227
Uttarakhand	1980-85	12.40		1394	-	-
	1986-90	11.45		1430	-	-
	1991-95	13.69	1.51	1104	52.70	-
	1996-2000	13.90		1067	51.80	-
	2001-2005	13.84		935	55.98	4180
	2006-2009	13.91		1245	31.66	-24320
H.P.	1980-1985	13.03		1323	46.80	-
Solan/Kangra	1991-2000	13.77		1270	83.20	36400
Mandi/Chamba/Sirmaur	2001-2007	14.40		1023	90.20	7000
	1980-1985	-		-	953	-404
Shimla/Kullu	2005-2007	-		-	549	16804
Kinaur/Lahul-Spiti	1980-1985	-	1.37	-	12368	20516
	2005-2007	-		-	29172	6433
	1980-1985	-		-	30975	
	2005-2007	-		-	51491	
	1980-1985	-		-	2532	
	2005-2007	-		-	8965	

Source -IMD, Srinagar

IV EFFECTS OF HIGH TEMPERATURE ON PLANT GROWTH AND FRUIT QUALITY

Plants can grow only within certain limits of temperature. Global warming enhances crop growth and, thus, shortens the period of fruit formation and number of fruits and seeds within may be reduced by the impacts of high temperatures on reproduction, particularly the formation and functioning of pollen (Larcher, 2003; Fischer and Orduz-Rodriguez, 2012). In peaches, a shortening of the earlier stages of fruit formation and development by elevated temperatures can reduce fruit size and yield (Stöckle *et al*., 2011). These studies also indicated that the shorter growing season would result in lowering of seasonal water loss by transpiration despite increase in temperature. Pritchard and Amthor (2005) reported that an increase in air temperature by a few degrees will significantly reduce the producing potential of many crops, which are currently grown in typical producing regions, moreover, extreme temperatures during anthesis, can severely affect harvest index. Countries in the northern hemisphere will benefit more from rising temperatures because the growing season will be extended (Swaminathan and Kesavan, 2012). Advanced flowering, due to the increase in temperature, as reported by Ramírez and Kallarackal (2015) occurs during several days, or even weeks, as compared to what happened 100 years ago, depending on the species. This reaction is more pronounced in the temperate zones than in the tropics or subtropics. Sherman and Beckman (2003) reported that peach cultivars with 80 days for fruit development, at an optimum temperature site, can take 120 days at a cooler place.

The temperature impacts the pace of physiological processes, with a profound influence on the kinetic energy of the enzymes and each fruit species has an optimum temperature range, in the case of cape gooseberry between 13 and 18°C, in the Andean blackberry between 16-19°C, etc. (Fischer and Orduz-Rodriguez, 2012). The increase in mean temperature can result in more flattened and less elongated fruits, more particularly when higher temperatures occur in the early phases of fruit development (Westwood, 1993). The rise in temperature reduces the duration of phenological phases, as counted in "heat units" or "degree days" expressing the heat accumulation above a base temperature (Parra *et al.*, 2015). The major effect on fruits quality in changing climate scenario are given as below:

4.1. Effects temperature on external parameters

4.1.1. Fruit quality

Each plant species has its own characteristic response to temperature. Most of the biological activities are very low or cease below 5°C. The exposure to very low temperatures impairs cell functioning and cause irreversible damage to plants. In recent years higher average temperatures during the receding winter in temperate areas is a major cause concern among the fruit growers as it leads to early bloom and maturity (Snyder and de Melo-Abreu, 2005).

4.1.2. Bud sprouting

The impact of temperature change is most in apple and almond where trees sprout 2-3 weeks early but normally apples trees sprout in mid April. As a result last few years about 70 per cent of trees began to open their buds in mid March. At the end of March it can definitely become very cold again. At this time most trees have their buds open are very susceptible to frost damage (Choudhary *et al.*, 2015).

4.1.3. Fruit size

Increase in temperature influences the size of fruits in different fruit tree species. In Cox and Queen Cox apple fruit size under polytunnel was enlarged as compared to cooler temperatures. The increased fruit size under high temperature treatment was attributed to decreased cropping intensity (Atkinson *et al.*, 1998). Fruit size is generally smaller, where low temperate occurs during spring which affects cell division in the post-bloom period.

4.1.4. Fruit color

Natural colour development in the fruits is one of the important quality parameter visibly sought after by the consumer. High temperature generally decreases the anthocyanin accumulation in fruit trees. In grapes, veraison is a critical period for the berry tissues to perceive environmental stimulation and trigger anthocyanin biosynthesis. Night temperature at this stage is more critical than the day temperature. Anthocyanin synthesis in the skin of berries grown at high night temperatures (30^{o}C continuous day and night) was reduced as compared to the berries grown at low night temperatures (30/15 ^{o}C; day/night). The reduced coloration at higher temperature has been correlated with decreased activity of Phenyl alanine synthase (PAL) (Boss *et al.*, 1996), Chalcone synthase (CHS) and UDPglucose, flavonoid 3-o- glucosyltransferase (UGFT) (Mori *et al.*, 2005). Environmental concerns such as global warming in the leading grape producing countries may further accelerate this problem. Similarly, in Starkrimson Delicious apples grown in the cooler environment (mean monthly temperature of 18.6 ^{o}C) showed rapid anthocyanin accumulation but warm weather at a different location (mean monthly temperature of 25 ^{o}C) was associated with slower anthocyanin biosynthesis. In this case, major interference due to temperature was reduced activity of PAL and less amount of reducing sugars (Li *et al*., 2004). In citrus, if mature fruits are left on the trees during summer months, chlorophyll returns to rind and carotenoid content decreases. This condition is referred to as regreening, degree of which is influenced by high temperatures.

4.1.5. Effect on internal parameters

Kiwifruit grown under high temperature (3-4 ^{o}C more than the ambient temperature) during mid March to mid May tend to have lower soluble solids, more firmness and higher starch concentrations in both core and cortex tissue (Hopkirk *et al*., 1989). However, in the grapes, the soluble solids content increased with the increase in temperature from 15 to 30 ^{o}C (Coombe *et al*., 1987).

4.1.6. Disorders

Early water core of apple cultivars where in sorbitol accumulation takes place was increased by high temperature above 30 ^{o}C during the summer (Yamada *et al*., 2004). These results implied that higher fruit temperature may increase tonoplast permeability especially to sorbitol in the early water core susceptible 'Orin' cultivar but not in resistant 'Fuji'.

Similarly fruits grown in high temperature, when stored at 3 ^{o}C, exhibited a breakdown incidence. It was more likely due to low calcium in the fruits at higher temperatures (Atkinson *et al*., 1998). In case of pear, higher temperature quickens the development of watercore (Sakuma *et al*., 1995). In pineapple, translucency of fruits is most commonly encountered disorder in which the flesh gives water soaked appearance. It poses a great hindrance in the fresh marketing of fruits. The incidence of the disorder was correlated with both higher (28/18^{o}C, max/min temperature) and lower (23/15 ^{o}C) 3 months preceding the harvest (Paull and Reyes 1996).

4.2. Effect on chilling requirements

Cool temperatures in the winter are essential for successful cultivation of many tree crops (Erez, 2000). All commercially important fruit and nut species having origin from temperate and cool subtropical regions require chilling period that need to be fulfilled each winter for homogeneous flowering and fruit set, and generate economically viable yields. If the tree receives insufficient chilling, associated physiological symptoms are manifested; that may include bud death, protracted vegetative and reproductive bud break and expansion, delayed or erratic, extended bloom, poor overlap with pollenizers, decreased fruit set and cropping and irregular fruit maturation.

If winter chill reduction occurs due to changing climate c, production constraints are likely to exceed those typically reported, because many tree species might not even come close to fulfilling their chilling requirements. In those circumstances, complete crop failures may frequently occur, while early senescence of trees will further result in reducing their yield potential, rendering many orchard operations uneconomical (Erez, 2000).

4.3. Effect on pollination

Pollinating agents such as, bees, birds, moths, flies, wasps, beetles, butterflies, bats and even mosquitoes are very important for food production because they transfer pollen between seed plants-impacting 35% of the world's crops. In addition to providing an essential service to human populations, pollinators also play a key role in maintaining additional ecosystem services including ensuring biodiversity and helping Nature to adjust to external disturbances such as climate change. The pollination crisis that is evident in the decline of honeybees and native bees is due to disruption of balance between the two mutually interacting organisms. Human induced climate change is widely expected to result in extinction of species by hampering individual survival and reproduction, by reducing the proportion and accessibility of suitable habitat, or by eliminating other organisms that are essential to the species in question. The potential imbalance of a ubiquitous mutualistic interaction of terrestrial habitats, that between plants and their animal pollinators, via climate change is at risk. Increasing temperatures affect flower production, flower size, timing of anthesis, floral scent, nector and pollen production in different crops (Abrol, 2012).

4.4. Effect on pre- cooling

Fruit crops are generally pre -cooled after harvest and before packing operations. Cooling techniques have been used to remove field heat from fresh produce, based on the principle that shelf-life is extended 2- to 3-fold for each 10^0C decrease in pulp temperature. Rapid cooling optimizes this process by cooling the product to the lowest safe storage temperature within hours of harvest. By reducing the respiration rate and enzyme activity, produce quality is extended as evidenced by slower ripening/senescence, maintenance of firmness, inhibition of pathogenic microbial growth and minimal water loss (Talbot & Chau, 2002). Rapid cooling methods such as forced-air cooling, hydrocooling and vacuum cooling demand considerable amounts of energy. Therefore, it is anticipated that under warmer climatic conditions, fruit and vegetable crops will be harvested with higher pulp temperatures, which will demand more energy for proper cooling and raise product prices.

4.5. Fruit ripening

High temperatures on fruit surface caused by prolonged expo- sure to sunlight hasten ripening and other associated events. One of the important examples is that of grapes, where berries that were exposed to direct sunlight ripened quicker than those ripened in shaded areas within the canopy. In the fruits exposed to direct sunlight, pulp temperatures reached 35 ^{0}C and required 1.5 days longer to ripen than those that grew in the shade (Woolf *et al*., 1999). Cell wall enzyme activity (cellulose and polygalacturonase) was inversely correlated with fruit firmness, indicating that sun exposure, i.e., higher temperatures during growth and development, can delay ripening. However this delay did not result via a direct effect on the enzymes associated with cell wall degradation. In apples, treatments of 38 and 40 ^{0}C for 2–6 days did not have marked effects on respiration, although ethylene production was reduced. High temperatures on fruit surface resulted by pronounced exposure to sunlight can increase ripening and other associated events.

4.6. Quality parameters

Flavor is affected by high temperatures. Apple fruits exposed to direct sunlight had a higher sugar content compared to those fruits grown on shaded sides. Increase in 10 oC increase in growth temperature caused a 50% reduction in tartaric acid content and malic acid synthesis is more sensitive to high temperature exposure during growth than was the synthesis of tartaric acid. Fruit firmness is also affected by high temperature conditions during growth. Changes in cell wall composition, cell number, and cell turgor properties were postulated as being associated with the observed phenomenon.

4.7. Antioxidant activity

Antioxidants in fruit crops can also be altered by exposure to high temperatures during the growing season. Strawberries grown with higher light intensity results increased levels of ascorbic acid. Growth strawberry under different growing temperatures (day/night) could also affect antioxidant activity and total fiavonoid content. High temperature conditions (25/30°C) significantly improved antioxidant activity, as well as anthocyanin and total phenolic content. Meanwhile, plants grown in the cool day and night temperature (18/12°C) treatment produced fruit that generally had the lowest antioxidant activity (Wang and Zheng, 2001).

4.8. Effect of temperature on frost susceptibility

Climate change will result in earlier growth and therefore to greater susceptibility to, and damage from, late spring frosts. Increase in winter temperature, anticipated in most of the scenarios, will lead to a very substantial increase in the number of days with temperatures above freezing, and above 5°C, thus extending and advancing the growing season. The concern expressed is that such an early onset of the growth as a result of changing climate may increase the risk of frost damage to plants. Although the occurrence of spring frost damage to precocious growth is not expected to enhance with climate change, there is some hint that autumn frosts may become more damaging. Reduced or delayed hardening of plants in the autumn combined with reduced cloud cover and an enhanced diurnal temperature range nay lead to increased damage. Frost damage may also occur during the dormant period, so the ability of plants to withstand winter frosts may also be affected by global warming.

V ADAPTATION STRATEGIES TO OVERCOME EFFECT OF CLIMATE CHANGE

Adaptation is the process through which people reduce the adverse effects of climate and adaptation measures are meant to protect a community against projected climate change impact. An understanding of the effects and relevant adaptation strategies are of utmost relevance to sustain the productivity and profitability of horticulture crops in the changing climatic scenario, which necessitates synthesis of current knowledge to develop strategies for adaptation and mitigation to produce climate-resilient horticulture.

5.1. Research strategies for optimizing production under changing climate scenario

5.1.1. Crop improvement strategies

- Harnessing the indigenous technical knowledge of fruit growers Adaptation of fruit crop
- Develop climate-ready crop varieties

- Introduction of low chilling cultivars of pome, stone and nut fruits.
- Development of new genotypes having resistance to high temperature and CO_2 concentrations.
- Marker assisted selection and development of transgenic having resistance to biotic and abiotic resistance.
- Development of genotypes having resistance to heat and drought.
- Biotechnological approaches for multiple stress tolerance will be standardized.
- Diversification with other high value fruit crops like peach, apricot, walnut, kiwi and olive.

5.1.2. **Development of agro-techniques**

- The phenology of pome, stone and nut crops under changing climate will be monitored and accordingly the package of practices needs to be developed.
- *In-situ* soil moisture conservation practices including indigenous technical know-how will be validated to mitigate the impact of drought.
- Development of suitable agronomic adaptation measures for reducing the adverse climate related production losses.
- Changing planting date and increased use of integrated farming system
- Study the impact of climate change and development of technologies on water productivity and water use efficiency.
- Identify and develop good practices to enhance the adaptation of crop to increased temperature, moisture and nutritional stress.
- Increase water saving technologies
- Identification and mapping of climate resilient as well as climatically vulnerable micro-niches in temperate regions.
- Extreme events, such as late spring frost or windstorm, may cause crop failure. Future climate may also increase occurrence of extreme impacts on crops, e.g. weather conditions resulting in substantial reduction in yield and quality (for example severe drought or prolonged soil wetness).
- To develop a set of high resolution daily based climate change scenarios, suitable for analysis of agricultural extreme events
- To identify climatic thresholds having severe impacts on yield, quality and environment for representative crops and to assess the risks that these thresholds will be exceeded under climate change.
- Provide more non-crop flowering resources in the field

5.1.3. **Plant protection strategies**

- Assessment of the pest and disease dynamics, study of disease triangle and development of prediction models
- Strengthen surveillance of pest and diseases.
- Development of ecofriendly pest- ecologies and management strategies and early warning systems.

- Development of IPM & IDM modules.

5.1.4. **Post harvest management strategies**

- Development of cost effective storage techniques.
- Development of varieties having longer shelf life.
- Studies on mitigation of post harvest spoilage.
- Development of technologies for field heat management.

5.1.5. **HRD & creating awareness**

- Organize seminars/symposia/trainings and conduct field demonstrations, on effective climate resilient technologies.
- Crop insurance

5.1.6. **Mitigation strategies**

- Land management strategies to increase soil carbon storage.
- Increase biomass to produce energy
- Increased use of composts.
- Restoration of degraded lands
- Intensive increase in reforestation
- Reduce emissions of greenhouse gases

VI. CONCLUSION

Changing climatic parameters has affected the normal growth and development, altered flowering behavior, influenced the quality fruit production and has brought about changes in pest and disease incidence. The phenology, geographic distribution and local abundance of plants and pollinators appear to be affected by recent climate change. Low winter chill affects tree behaviour such as flowering and lack of uniformity. In the light of possible impact of climate change, researchers should more emphasis on development of heat- and drought-resistance crops. The research programme also needs to be initiated to find out available chilling and to define the current limits to these resistances and the feasibility of manipulation through modern genetic and production techniques.

REFERENCE

1. Anonymous, *horticultural statistics at a glance*, 2017.
2. IPCC, *Climate change 2007: The physical science basis*, In: S. Soloman, D. Qin, M. Manning, Z. Chen, M.
3. M.E. Mann, R.S. Bradley, and M.K. Hughes, Northern hemisphere temperatures during the past milliennium: inferences, uncertainties, and limitations. Geophysical research letters, 26(6), 1999, 759-762.
4. R. Henson, *The rough guide to climate change* (2nd ed.), Penguim Books, London, 2008, 384p.
5. N, Ahmed, and S. Lal, *Climate change: impact on productivity and quality of temperate fruits*, In: In book: climate dynamics in horticultural science, *Volume I*

6. M.L. Choudhary, V.B. Patel, M.W. Siddiqui, and S.S. Mahsi, *Climate dynamics in horticultural science volume-I: principles and applications*, Apple academic press, 2015.
7. H. Chand, S.C. Verma, S.K. Bhardwaj, S.D. Sharma, P.K. Mahajan, and R. Sharma,. Effect of changing climatic conditions on chill units accumulation and productivity of apple in mid hill sub humid zone of Western Himalayas, India, Current World Environment, 11(1), 2016, 142-149.
8. W. Larcher, *Physiological plant ecology* Springer-Verlag, Berlin, 2003. Doi: 10.1007/978-3-662-05214-3.
9. G. Fischer, and J.O. Orduz-Rodriguez,. *Ecofisiologia en frutales* pp. 54-72, In: G. Fischer, (ed.)., *Manual para el cultivo de frutales en el trópico*, Produmedios, Bogotá, 2012.
10. C.O. Stöckle, J. Marsal, and J.M. Villar, Impact of climate change on irrigated tree fruit production, *Acta Hort, 889,* 2011, *4152. Doi: 10.17660/Acta Horti.,* 2011.*889.2.*
11. S.G. Pritchard, and J.S. Amthor, *Crops and environmental change* Food Products Press, The Haworth Press, New York, NY, 2005.
12. M.S. Swaminathan, and P.C. Kesavan, Agricultural research in an era of climate change, *Agric. Res*., 1, 2012, 3-11. *Doi: 10.1007/s40003-011-0009-z.*
13. F. Ramirez, and J. Kallarackal, *Responses of fruit trees to global climate change* Springer Briefs in Plant Science, *Springer International Publishing*, New York, NY, 2015.
14. W.B. Sherman, and T.G. Beckman, *Climate adaptions in fruit crops, Acta Hortic. 622*, 2003, 411-428. *Doi: 10.17660/Acta Hort.,* 2003.*622.43*.
15. M.N. Westwood, *Temperate-zone pomology: physiology and culture* 3rd ed., Timber Press, Portland, OR, 1993.
16. Parra, G. Fischer, and B. Chaves, *Tiempo térmico para estados fenológicos reproductivos de la feijoa (Acca sellowiana (O. Berg) Burret), Acta Biol. Colomb., 20*, 2015, *167-177*.
17. R.L. Snyder, and J.P. de Melo-Abreu, *Frost protection: fundamentals, practice, and economics, Volume 1*, Rome: FAO, 2005, pp. 223.
18. P.K. Boss, C. Davis, S.P. Robinson, Analysis of expression of anthocyanin pathway genes in developing *Vitis vinifera* L. cv. Shiraz grape berries and the implications for pathway regulation, *Plant Physiol., 111*, 1996, 1059-66.
19. K. Mori, S. Sugaya, H. Gemma, Decreased anthocyanin biosynthesis in grape berries under elevated night temperature condition, *Scientia Hort*., 105, 2005, 319-30.
20. X. Li, J.H. Hou, G. Zhang, R.S. Liu, Y. Yang, J. Lin, Comparision of anthocyanin accumulation and morphoanatomical features in apple skin during color formation at two habitats, *Scientia Hort*., 99, 2004, 41-53.
21. G. Hopkirk, W.P. Snelgar, S.F. Horne, P.J. Manson, Effect of increased preharvest temperature on fruit quality of kiwifruit (*Actinidia deliciosa*), *J Hort. Sci., 64*, 1989, 227-37.
22. B.G. Coombe, Influence of temperature on composition and quality of grapes, *Acta Hort*., 206, 1987, 23-35.

23. H. Yamada, K. Takechi, and S. Amano, Comparision of water relations in watercored and non – watercored apples induced by fruit temperature treatment, *Scientia Hort*., 99, 2004, 309-18.
24. C.J. Atkinson, J.M. Taylor, A.S. Lucas, Temperature and irrigation effects on the cropping, development and quality of Cox's Orange Pippin and Queen Cox apples, *Scientia Hort*., 75, 1998, 59-81.
25. F. Sakuma, T. Umeya, K. Tahita, and H. Hiyama, Effect of high temperature and gibberellin treatments during early fruit development on the occurrence of watercore in Japanese pear (*Pyrus pyrifolia* Nakai cv. Hosui), J Japanese Soc. *Hort. Sci., 64*, 1995, 243-49.
26. R.E. Paull, and M.E.Q. Reyes, Pre-harvest weather conditions and pineapple fruit translucency. *Scientia Hort., 66,* 1996, 59-67.
27. A.Erez, *Bud dormancy; phenomenon, problems and solutions in the tropics and subtropics*, In: A. Erez, (ed.)., *Temperate Fruit Crops in Warm Climates*, Dordrecht, The Netherlands: Kluwer Academic, 2000, pp. 17–48.
28. D.P. Abrol, Climate change and pollinators. In: Pollination biology, *Springer, Dordrecht*, 2012.
29. M.T. Talbot, and K.V. Chau, Pre-cooling strawberries agricultural and biological engineering department, florida cooperative extension service, Gainesville: Institute of Food and Agricultural Sciences, University of Florida, Bulletin 942, 2002. 11p.
30. A.B. Woolf, J.H. Bowen, and I.B. Ferguson, Pre-harvest exposure to the sun influences postharvest responses of 'Hass' avocado fruit, Postharvest Biology and Technology, 15, 1999, 143–153.
31. S.Y. Wang, and Zheng, W, Effect of plant growth temperature on antioxidant capacity in strawberry, *Journal of Agricultural Food Chemistry, 49*, 2001, 4977–4982.