Review Article ______________________________________ *Chapter – 11*

CLIMATE CHANGE IMPACTS ON ORCHARD MANAGEMENT: A REVIEW

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Abstract

Climate change now a day is globally acknowledged fact. Considering the declining production efficiency of agro-ecosystems due to depleting natural resource base, serious consequences of climate change on diversity and performance of fruit trees, food security for 21st century is the major challenge for human kind in years to come. Being a tropical country, India is more challenged with impacts of looming climate change. In India, performance of fruit trees varies in different agro-climatic regions across the country mainly due to differential impacts of abiotic factors such as temperature, humidity and rainfall. This entails the intensification of yield losses due to potential changes in crop diversity and increased incidence of biotic and abiotic stresses due to changing climate. It will have serious environmental and socio-economic impacts on rural farmers whose livelihoods depend directly on the horticulture and other climate sensitive sectors. Dealing with the climate change is really tedious task owing to its complexity, uncertainty, unpredictability and differential impacts over time and place. Understanding abiotic and biotic stress responses in fruit plants, orchard management is an important and challenging topic ahead in agricultural research. Impacts of climate change on fruit production mediated through changes in orchard management practices need to be given careful attention for planning and devising adaptation and mitigation strategies for future orchard management programmes with respect to climate change.

Keywords: Climate change, Fruit crop, Global warming, Physiology

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Introduction

This Climate change is no more a distant problem. It has been experiencing globally through changes in climatic variables, such as temperature variations, variable rainfall, frequent droughts, hurricane and typhoons (Lobell *et al*., 2012; Auffhammer *et al*., 2011), and have almost failed to reach a global consensus on the mitigation of greenhouse gas (GHG) emissions (Sharma, 2015). Additionally, policymakers in developed nations have shrugged off the whole notion of climate change. However, many countries have recognized the effects of climate change and have adopted measures to reduce its impact. As a result, response to climate change has not been addressed properly. Additionally, Fussel (2007) notes that slow mitigation response will not reduce adverse effects of GHGs that is already in the atmosphere. Poor people living in agricultural communities in developing countries are expected to be the most affected by these climatic changes (Maskrey *et al*., 2007). Developing countries are most vulnerable to climate change though they are only contributing 10% to the annual global carbon dioxide emissions (Maskrey *et al*., 2007). South Asian countries are particularly affected because of the vast populations still dependent on predominantly agriculture-based rural economies and the vast number of poor people. This poses serious challenges to their social, economic and ecological systems (Zhuang, 2009). India is too affected by climate change and it is predicted that temperatures will rise by 2.7- 4.3°C over India by the 2070 with warming more pronounced in the northern parts of India. Rainfall over the Indian sub-continent will rise by 6-8 percent and that the sea level would rise by 88 centimeters by 2100. An annual mean surface temperature rises by the end of this century, ranges from 3°C to 5°C with a 20 per cent rise in all India summer monsoon rainfall. A further rise in rainfall is projected all over the India except different regions of Punjab, Rajasthan and Tamil Nadu, which show a slight decrease in rainfall patterns.

The extreme weather events of hot and cold wave conditions have been reported to cause considerable damage to many fruit crops. In perennial crops like mango and guava, temperature is reported to have influence on flowering. Mango has vegetative bias, and this becomes stronger with increase in temperature, thus influencing the flowering phenology. The percentage of hermaphrodite flowers was greater in late emerging panicles, which coincided with higher temperatures (Singh *et al*. 1966, Ramaswamy and Vijay Kumar 1992, Balogoun *et al*. 2016). During peak bloom period, high temperature (35ºC) accompanied by low relative humidity (49%) and long sunshine hours resulted in excessive transpiration and dehydration injury to panicles. Leaf scorching and twig dying are common symptoms of heat stroke in bearing and non-bearing mango plants. Major observed effects of climate change on mango include early or delayed flowering, multiple reproductive flushes, variations in fruit maturity, abnormal fruit set and transformation of reproductive buds into vegetative ones (Rajan *et al.* 2011). In guava, there is severe increase in pests and diseases due to hot and humid conditions. Fruit fly in guava is becoming alarming due to hot and humid conditions. The crop like peach, plum, which requires low chilling temperature also showing sign of decline in productivity (Hazarika 2013). High temperature and moisture stress also increase sunburn and cracking in apples, apricot and cherries. Increase in temperature at fruit maturity lead to fruit cracking and burning in litchi (Kumar and Kumar 2007) and premature ripening of mango. Untimely winter rains promote vegetative flushes in citrus instead of flowering flushes. Dry spell during flower emergence and fruit set affects flower initiation and aggravates incidence of pest. Many slow-growing fruit crops require heavy investment on establishment of orchards. Since many crops with chilling requirements are tree species, moving production areas is difficult. Thus, in replanting orchards and plantations over the next decade, selection of lower-chilling requiring types may be advisable. Drought, temperature extremes and saline soils are the most common environmental threats. Diseases both in field and storage accounts for 25-30 per cent losses in fruit crops (Rangaswami and Mahadevan, 2002). There are 600 insects and mite pests are present in temperate fruits alone in India (Sharma *et al* 2005). No matter how favourable the climate may be for fruit production, there are in all regions occasional extremes which damage the fruit or the trees. Man has little control over the climate, but can in some cases decrease the amount of damage.

Climate change adaptation is an emerging field that focuses on preparing for, coping with, and responding to the impacts of current and future climate change. More formally, climate adaptation has been defined as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (IPCC 2007a) and "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007b). As these definitions suggest, climate adaptation focuses primarily on human responses to climate change (either active or passive), as distinct from use of the term "adaptation" in the traditional evolutionary biology sense, which focuses on genetic changes over time in response to selective pressures. Although they are different concepts, evolutionary adaptation plays an important role in climate adaptation, particularly in terms of the capacity of species and populations to naturally adjust to changing conditions through genotypic shifts or phenotypic plasticity (Hoffman and Sgro 2011). Unless otherwise noted, however, here "adaptation" refers specifically to climate adaptation.

Different Approaches taken to overcome these climatic stresses in fruit orchards are described below:

1. Global Information System (GIS)/ Crop Modeling Approach

Matching fruit crops to climate is an important physiological factor for profitable fruit production. Important climatic factors like growing season, thermal time, winter chilling, annual rainfall and several of the interaction variables can be identified as determinants of fruit production. The mapping of such indices can best b validated by comparison with the known commercial area of fruit crop. The climate suitability models for mango varieties have been developed using algorithm for rule set prediction (GARP), maximum entropy (MAXENT) and bio- climate (BIOCLIM) for determining/ mapping the potential areas. The comparison of MAXNT and BIOCLIM mapping for suitable areas for cultivation of Alphonso was found similar. It showed that north and northern eastern parts of the country are not suitable for this cultivar. Apart from Ratnagiri, area near Jamnagar in Gujarat has been as suitable with both the models. Similarly, areas suitable for red color guava have been mapped by extracting climatic information from the areas of successful cultivation like Allahabad, Fetehpur, Raibar;li and Lucknow districts. An analysis of climate data showed that the areas where minimum temperature is 8-10 degree are suitable for the production of red color guava. Subtropical belt starting from Jammu to Varanasi can be used for this purpose.

Litchi is another fruit crop which is very specific in its climatic requirement. A geographical investigation System (GIS) based approach to investigate differences in environmental factors characterizing the geographical distribution of litchi was used. Locality data of litchi growing areas were used in conjunction with the environmental data layers for calibration to compare climate probability model. Some of the regions identified as the most suited have been under cultivation for decades but few other have potential and not yet exploited for litchi cultivation. Cluster analysis of climatic requirement of litchi varieties indicated that different varieties will be suitable for different areas like Pusa, Surguja, Ambikpur, siwan bazaar, Ranchi, Khalilabad when compared with areas like Dehradun, Ramnagar, Rampur, Sitarganj, Pantnagar, Haldwani. Varieties near to the coastal regions in the litchi growing areas of Westbengal, Tripura, Tezpur will be different. Suitability mapping indicated that quality litchi can be produced in areas like Deoria in U.P; Majurbhanj and Kanduljhar in Orissa. It can be successfully grown in Betul, Chindwara and Jagdalpur districts. The mapping of agro-climate zones is well established method for delineating areas suitable for particular land uses for specific crop types.

2. Weather Forecasting

The effects of climate change can be reduced to considerable extent is we have strong weather forecasting system in place it is timely passed on to the fruit growers. The probable impact of drastic climate change and suitable precautions to face it need to be conveyed well in advance so that pro-active steps can be undertaken.

3. Agronomic Management System/Specific Cropping System

Cropping system means cropping pattern and its management to derive benefits from given resource under specific environmental condition. It changes when place and environment is changed. It means cropping system is location specific. The cropping pattern used on the farm and their interaction with farm resource, other farm enterprises and available technology determines the makeup of cropping system thus cropping system includes the pattern of crops taken for a given piece of land, or the order in which the crops are cultivated on a piece of land over a fixed period, associated with soil management practices such as tillage, manuring and irrigation.

The objective of any cropping system is efficient utilization of all the resources viz. land, water and solar radiation, maintaining stability in production and obtaining higher net returns. The efficiency is measured by the quantity of produce produced per unit resource in a unit area.

Modern scientific cropping system has three pillars

- Genotype of crop
- Geometry of planting
- Management practices

The various agronomic strategies to overcome environmental threats are given by;

a) Development of cropping systems under various agro- climatic conditions
b) Improvement in the irrigation and drainage systems
c) Development of appropriate tillage and intercultural operations
d) Integrated nutrient management
e) Integrated pest management.
f) Integrated weed management
g) Development of water harvesting techniques
h) Waste land utilization
i) Use of modern technological tools for weather
j) Development of pest and disease forecasting systems

Das *et al.* (2011) conducted an intercropping trial during 2007– 2010 on 6-year-old aonla (*Emblica officinalis* Gaertn.; cv. NA-7) orchard planted at 6 m × 6 m spacing and growing under rainfed calciorthent soil, to identify the suitable and profitable intercrops. The intercrops grown were turmeric, ginger and arbi. The results indicated that the production of fruits significantly increased due to intercrops and it was maximum in aonla in association with turmeric (13.30 tonnes/ha) followed by arbi (11.71 tonnes/ha). On the other hand, reduction in yield of intercrops was 7.5–12.0% for turmeric, 12.2–19.3% for ginger and 15.7–25.3% for arbi compared to the yield in open area without trees. It was confirmed that aonla-based agri-horticultural systems were effective in bringing about improvement in the soil properties as reflected by the significant increase in organic carbon, available nitrogen and phosphorus. Economic analysis of the systems in terms of benefits : cost ratio revealed that 'aonla + turmeric' gave a higher value (6.29) followed by 'aonla + ginger' (3.44) and 'aonla + arbi' (3.20). The interspaces of the aonla orchard in calcareous belt of eastern India could be utilized for growing various intercrops to generate substantial additional income without adverse effect on the soil fertility and productivity of the main crop.

The cultivation of legumes and grasses as intercrop is becoming popular in orchards. The important legumes are red clover (*Trifolium pratense*), white clover (*T. repens*) and lucern (M*edicago sativa*). Among the grasses, orchard grass (*Dactylis glomerata*), fescues (*Festuca arundiceae*) and Timothy (*Phleum pratense*) are common. Orchard grass is grown where moisture is high, while fescues is suitable for dry areas or southern aspects. In apple, sometimes filler trees of peaches or dwarf apple plants are grown**.**

Agroforestry systems buffer farmers against climate variability, and reduce atmospheric loads of greenhouse gases. Agroforestry can both sequester carbon and produce a range of economic, environmental, and socio-economic benefits. Agroforestry systems improve soil fertility through control of erosion, maintenance of soil organic matter and physical properties, extraction of nutrients from deep soil horizons and promotion of more closed nutrient cycling.

Various on farm mitigation strategies to protect fruit plants from various environmental threats are summarized as;

- Rain water harvesting, checking sub soil water depletion helps to eliminate water stress during drought.

- Balanced nutrient management helps in better adaptation against climatic vagaries.
- Erection of wind breaks and individual tree and fruit protection systems can protect from severe winter and summer temperature and winds.
- Mulching improves root functioning resulting in better plant growth and elimination of heat and cold stress.
- Use of micro irrigation system increases WUE and hence reduces wastage of water.
- Use of green manures, bioagents and plant based pesticides can help in lowering in greenhouse gases.

The various orchard management stratergies under different climatic variants are given bellow:

A. Management of Low Temperature/ Frost

Fruit species and varieties vary in their proneness to frost largely because of their different flowering times, Red Gaunlet, Vesper, Dobrishka and Gorella varieties of strawberries are resistant to low temperatures having more than 40 % plant survival when exposed temperature below -7º C (Peikove and Stankova 1990). Van and Stella are cold tolerant cultivars of sweet cherry (Petre 1987).

Use of cold hardy rootstocks can also effective to overcome frost injury. Manchurian, Almey, September, C-52, MM 106, and Ottawa 3 rootstocks of apple are cold hardy and can tolerate low temperature range from -33º to -35.5º C (Holubowicz *et al.* 1982), Hamlin grafted on winter hardy rootstocks Cleopatra show minimum frost damage to the shoots (Gupta *et al* 1978). Yelenosky and Hearn (1977) reported that Ester Rough lemon rootstocks seedlings showed 100 % survival after 2 months of 3 consecutive freezes. Cold hardiness cultivars of apple have been reported to develop by utilizing cold hardiness species of *M. punifolia* and *M. baccata* in hybridization work (Strang and Stushnoff 1975). Studies using plants bearing mutations in hormone-biosynthetic pathways have been instrumental in advancing our understanding of the processes associated with the plant responses to changing environments. Delayed flowering can greatly help in escaping damage. Durner and Gianfagna (1991) reported that ethephon prolongs flower bud dormancy by increasing the chilling requirements in peach flower buds. The rate at which flower buds become increasingly sensitive to moderate temperatures in late winter and spring and thus reduces by ethephon ,young and mature peach trees cv Dixired sprayed with SADH at 10,000 ppm during January and February delayed flowering and reduced the risk of damage by late frost (Guerriero and Scalabrelli 1998). The bloom delay might be associated with its action in decreasing the concentration of gibberellins in the young flower buds, which in turn reduce their capacity to attract, assimilates and thus delayed the blooming (Manhenett 1979). Siberian C rootstock delays bloom period in peach and prevent the peach bloom from late spring frost injury (Young and Reid 1989).

The shoots of chloromequat (TUR) treated lemon tree ceases to grow earlier than in untreated tree and thus show more frost tolerant (Rosnadze *et al* 1989). The chemicals which inhibit growth tend to increase hardiness. Wolfel and Noga (2000) reported that flowering branches of apple treated with a mixture of alpha-tocopherol (0.25%) and glycerol (5%) were more resistant to frost. Application of 600 ppm of succinic acid in January to almond delays blooming and results in maximum yield (Jhoolka *et al* 1991). Exogenous salicylic acid potentially alleviates the damaging effects of low temperatures in banana (Kang et al 2003). ABA acts as a mediator in plant responses to a range of stresses, including drought and salt stress. The application of exogenous PAs has been useful to identify the association of their stress accumulation with plant tolerance under abiotic stress (Kriticos, *et al*. 2003). Besides these GR's, BR, JA, CK's, GA's etc have been successfully used in herbaceous crops under stress conditions but have not been reported in fruit crops.

Use of chemicals which directly influence cellular properties and increase plant tolerant to extracellular ice and accompanying dehydration are also effective to overcome frost damage. Steffens *et al* (1988) reported that detached shoots apple cv Anna, Red Delicious and Northern Spy when treated with thidiazuron and stored at 4º C, reduce the number of chill units required to release bud dormancy. Cryoprotectants compounds can also be applied to plants to increases freezing resistance. The addition of cryoprotectants reduces the amount of ice formed, decrease the amount of cellular dehydration and reduce the internal concentration of salts and potentially toxic compounds at any given temperature (Meryman and Williams 1985). Pyke *et al* (1988) evaluated insulation wraps for frost protection of kiwifruit trunks and reported that under frost conditions the minimum temperature inside all trunk wrap was greater than that on an unwrapped trunk. Frost buster used for blowing off heated air between fruit trees effectively prevent frost damage to flowers of pear and apple trees (Deckers and Schoofs 2001).Warmer air can extracted from up to 12 m above ground level is circulated in flexible plastic tubes laid alongside the tree rows at ground level effectively prevent frost damage (Ventura 2000).Wind machines used to protect commercial acreage from frost by mixing warmer air along with cooler air near surface ,thus maintaining warmer minimum temperatures within the orchards (Connell and Snyder 1999). Mee (1987) reported that manmade fog raised plant tissue temperature by 4.5º C and was more effective than wind machines in a citrus orchard. By irrigating the orchard, it is possible to raise the temperature by 2-5ºC.Irrigation is helpful if the frost is of short duration, but frost lasting for several days causes loss of heat from the sun during the day. Cold tolerance in citrus is manipulated by genetic transformation by inserting genes responsible for cold tolerance in other plants or antifreeze protein genes from animals (Culter *et al* 1989). The antifreeze protein gene (Cn-AFP) from the Antarctic marine diatom, *Chaetoceros neogracile* was cloned and characterized.

- Northern analysis demonstrated a dramatic accumulation of Cn-AFP transcripts when the cells were subjected to freezing stress.
- This rapid response to freeze stress, and the antifreeze activity of recombinant Cn-AFPs, indicates that Cn-AFP plays an important role in low temperature adaptation. (Gal *et al*. 2010)

Percival *et al* (2002) reported that ice-nucleating bacteria associated with frost injury may be controlled by genetically engineered ice-minus bacteria. Ice-minus technology is designed to depress the critical temperature at which frost injury begins by displacing the natural population of ice-nucleating organisms.

B. Management of High Temperature

Choice of proper rootstock is one of the most important ways of avoiding damage due to supra optimal root temperature. Thompson seedless grafted on Dogridge and No. 1613 showed least fruit injury by high temperature (Harmon and Synder 1973). Gur *et al* (1976) reported that there was minimum reduction in fresh weights of roots of apple rootstocks M 25 and M 7 when grown at 35º C whereas it was highest in Italian Doucin and Khashabi rootstocks. Wang *et al* (2007) tested three rootstocks to verify whether graft can improve the tolerance to high temperature of eggplant grown in solar greenhouse during summer season or not. The results revealed that rootstocks could prolong the growth stage of eggplant and best rootstock was found to be Nianmaoqie. Trees of Olive cv. Amphissis treated with paclobatrazol (PBZ) applied as a drench 25ºC days before the beginning of flowering when exposed to maximum temperature of 32º C during flowering and 35º C for one week showed higher fruit set (23.1 %) than the untreated control trees (12.6 %) (Porlingis *et al* 1999). Young trees can be fairly easily protected by erecting light thatches over them, or by erecting temporatory mud walls around them, or both. Sunburn of the leaves, fruits, and bark is sometimes a serious factor. Permanent or temporary shade trees afford some protection against damage. The bark may be shaded by wrapping paper around the limb or whitewashed may be applied, which causes much of the light reflected and thus prevents the bark from becoming as hot as it otherwise would.

Wind breaks used to reduce wind travel over crops reduce mechanical stress, reduce evaporation and decrease water use. Frequency of irrigation should be increased during the hot period of May and June when desiccating winds generally blow and cause higher losses due to evaporation and transpiration. Use of hail nets reported to reduce the maximum temperature at hot days.

Mulching reported to increase soil moisture by 41 % and adjusted soil temperature (Lu and Zhao 1998). Basooti mulch reduced soil temperature by 1.5 º C as compared to 2.4ºC recorded in control up to 20 cm depth (Aulakh and Sur 1999). Straw mulching was investigated as a method of improving economies of water use and pear fruit quality in arid desert region. Pear growth curves of fruit width and length showed that the rapid growth period of the fruit lengths with straw mulching was longer than that when no straw mulching was applied. Wind breaks used to reduce wind travel over crops reduce mechanical stress, reduce evaporation and decrease water use.

Lack of sufficient cold weather in the winter sometimes causes delayed foliation and the failure of the crop when certain deciduous fruits, particularly peaches are grown in subtropical regions. These trees seem to require a certain amount of cool weather to break the rest period, and following a mild winter may remain dormant well into summer. Camelatt and Nachtigall (1998) reported that Gala apple trees sprayed with 150 mg/l thidiazuron plus 4 % mineral oil or 0.25 % HCN plus 4 % mineral oil gave best results in terms of improves bud break. Treatment of peach shoots with GA 100 mg/l alone or in combination with zeatin broke dormancy and promoted sprouting (Gao *et al 1999*). The best permanent solution to overcome high temperature lies in breeding and selection for varieties which have very low chilling requirements. The low-chilling cultivars of peach are Early Amber, Early Grande, Flordabella, Flordagold, Florda Sun, Sharbati and Ray Gold can be cultivated in subtropical regions (Sherman *et al* 1986).

C. Management of Water Deficiency

Mulching minimizes water losses from soil surface as a result of solar radiation and wind action. Lu and Zhao (1998) reported that mulching an apple orchard with straw significantly increased soil moisture by 41 % and adjusted soil temperature compared with control. Aulakh and Sur (1999) observed the effect of different mulches in pomegranate and investigated that polyethylene mulches conserved the higher soil moisture (4.1 %) than control (Table 1):

Table 1: Effect of Mulching on Soil Temperature, Soil Moisture, Weed Population, Growth and Yield in Pomegranate

Treatment	Soil Temperature (°C)	Soil Moisture (%)	Number of weeds	Fruits yield (Number)
Black Polythene	27.06	11.93	19.7	32.6
White Polythene	26.87	11.62	26.4	30.7
Farmyard Manure	23.11	11.17	240.1	27.5
Basooti	22.81	11.01	82.7	26.4
Control (No mulch)	24.28	7.79	112.7	176.3

Antitranspirants used under water stress conditions can be categorized into four types such as Stomatal closing type (PMA, Atrazine), Film form type (Tag 9, S-789), Reflective type (kaolin, celite, hydrated lime, calcium carbonate, magnesium carbonate, zincs sulphate etc) and Growth retardants (Cycocel). Spray of antitranspirant chemicals on the tree foliage either reduce the incidence of radiant energy or check losses by physical impedance or through stomatal closure. Kaolin, a radiation reflectant sprayed on pomegranate foliage at 5-8 per cent concentrations effectively reduced transpiration rate (Anon. 1989).

In a two year study, Masoud (2012) reported that in apricot cv. Hamawy, use of antitranspirants (Green miracle @ 1%) could effectively increase fruit yield, fruit weight, no. of fruits per tree and can also significantly reduce fruit drop (Table 2).

Rehman (2010) reported that CCC and PP 333 treatments sprayed at 500 and 1000 ppm gave the highest values of fruit physical and chemical properties on Barrani grapevines as compared with effect of pruning, vapour-guard at 4,6 %, paraffin wax at 8, 10 % (as antitranpirants). The 10 % solution of the antitranspirant Wilt Purf plant protector when applied on peach trees following harvest, water use of the treated trees was reduced by 40 % immediately after application and by 30 % one month after treatment as compared to control (Steinberg *et al* 1990). Plants having xerophytes characteristics *viz*. Deeper root system, deciduous in nature, reduced foliage, sunken or covered stomata, waxy coating and hairy leaves etc. minimize the evapotranspiration and make the plants amenable for their cultivation under the moisture stress situations. Fruits like cashew nut, custard apple, ber, aonla have xerophytic characteristics and may be cultivated under moisture stress situations (Pareek and Sharma 1993 and Vashishtha 1999). Naor *et al* (2008) reported that midday stem water potential in *Malus domestica* trees at Ortal decreased with increasing crop load in 1 mm/day, decreased slightly with crop load in the 3 mm/day treatment and was unaffected by crop load in the7mm/day treatment. In contrast, midday stem water potential in trees at Matityahu decreased with increasing crop load at all irrigation rates.

Table 2: Effect of Some Antitranspirants on The Percentage of Preharvest Fruit Dropping, Yield and Fruit Weight (G.) of Hamawy Apricot Trees During 2010 and 2011 Seasons (Masoud, 2012)

Treatment	Pre harvest fruit drop		No. of fruits/tree	
	2010	2011	2010	2011
Control	38.9	40.0	281.0	284.0
Green miracle at 1.0 %.	7.0	7.3	350.0	356.0
Green miracle at 2.0 %.	5.9	6.0	380.0	387.0
Kaolin at 1.0 %	15.0	14.0	330.0	338.0
Kaolin at 2.0 %.	9.2	10.6	355.0	364.0
Vapor guard at 1.0 %.	21.0	20.0	296.0	304.0
Vapor guard at 2.0 %.	18.0	17.5	307.0	318.0
Treatment	Yield/tree		Fruit weight	
	2010	2011	2010	2011
Control	16.6	16.6	59.0	58.5
Green miracle at 1.0 %.	27.3	27.1	78.0	76.0
Green miracle at 2.0 %.	31.5	31.3	82.9	80.8
Kaolin at 1.0 %.	32.2	23.1	70.3	68.2
Kaolin at 2.0 %.	26.3	26.5	74.0	72.9
Vapor guard at 2.0 %.	20.6	21.2	67.0	66.6

Growth retardants reduce the water requirement of fruit crops thus effectively overcome moisture stress. Paclobutrazol treated plants lost less moisture than those from the control plants. Frakulli *et al* (1999) reported that olive plants treated with growth retardants paclobutrazol and triapenthenol showed a significant decrease in their daily and total water use and increase drought resistance. Paclobutrazol can effectively protect fruits from stress injury in the dessert. Use of drought resistant cultivars and rootstocks also effectively control moisture stress. Atkinson *et al* (1998) reported that AR 295/6 and AR 486/1 apple rootstocks had well developed root system and were most tolerant to drought. *P.calleryana* seedling tolerant a wide range of soil texture and soil moisture. D-6 strain is drought tolerant. (Lombard and Westwood 1987). Myrobalan and Mariana plum rootstocks tolerate heavy soils and poor drainage better than peach and apricot rootstocks. Myrobalan rootstock is resistant to drought. (Okie 1987). Kaynas *et al* (1997) investigated drought resistance of Granny Smith and Amasya apple cultivars grafted on M9, MM 106 and seedling rootstock and reported that both cultivars were more drought resistance when grafted on M 9 and seedling rootstocks than on MM 106. Prakash *et al* (2001) reported that Dogridge, Salt Creek and *Vitis champini* could survive under 100 % moisture stress and there was marginal reduction in net photosynthesis rate. Kronenberg (1990) designed a stress index to prevent Cox disease which can be considered as symptom of water stress to find places where commercial production of Cox's orange pippin is feasible.

D. Management of Water Excess

The roots suffocate in areas experiencing heavy rains and having no proper drainage. The uptake of nutrients also gets adversely affected, because of lack of oxygen in soil. N, B, Mg, and K are highly soluble in water and go deeper in the soil, below root zone, causing their temporary deficiency. The sooty blotch and fly specks are more prominent on fruits and affect their quality. Fruit skin colour becomes dull and dark. Fruit tends to be watery, as against being juicy due to excessive rains. Fruit drop and fruit cracking are the severe problems in some fruits due to heavy rains.

Use of cultivars and rootstocks tolerant to stagnant water are effective to overcome high rainfall. Salem (1991) studied on tolerance to water logging on 3 citrus rootstocks i.e. sour orange, Cleopatra mandarin and *C. volkameriana* and reported that *C. volkameriana* has ability to tolerate water logging stress. Fernandez *et al* (1998) treated 7-year-old trees of sweet cherry cultivars Ulster and Emperor Francis with 1 % $CaCl_2$ and reported that $CaCl_2$ treated trees showed less cracking percentage (9 and 13%) as compared to control (43 and 22 %) in both cultivars. Similarly, Howard *et al* (1998) reported significantly less splitting (18%) from CaCl2 treated trees than from untreated trees (36% splitting). Sankhla *et al* (1989) reported that paclobutrazol greatly reduced cracking of fruits caused by excessive moisture. Chaplin *et al* (1974) reported that peach scions grafted on Rutgers red leaf rootstock can tolerate excess moisture and poor drainage. *Pyrus betulifolia* plants showed 100% survival when flooded for 20 months continuously (Anderson *et al.* 1984). Zilberstaine *et al* (1999) reported that during autumn when the climate conditions are conductive to fire blight epidemics, removal of off-season flowers avoid the *Erwinia amylovora* infection in pears.

E. Management of Salinity Conditions

Saline soils cannot be reclaimed by chemical amendments, conditioners or fertilizers. A field can only be reclaimed by removing salts from the plant root zone. For most surface irrigation systems (furrow and flood), irrigation in efficiency (or over-irrigation) generally is adequate to satisfy the leaching requirement. However, poor irrigation uniformity often results in salt accumulation in parts of a field or bed. Surface irrigators should compare leaching requirement values to measurements of irrigation efficiency to determine if additional irrigation is needed. Adding more water to satisfy a leaching requirement reduces irrigation efficiency and may result in the loss of nutrients or pesticides and further dissolution of salts from the soil profile. Planned periodic leaching events might include a post-harvest irrigation to push salts below the root zone to prepare the soil (especially the seedbed/surface zone) for the following spring. Fall is the best time for a large, planned leaching event because nutrients have been drawn down.

Where shallow water tables limit the use of leaching, artificial drainage may be needed. Cut drainage ditches in fields below the water table level to channel away drainage water and allow the salts to leach out. Drainage tile or plastic drainpipe can also be buried in fields for this purpose The advantage of artificial drainage is that it provides the ability to use high quality, low salinity irrigation water (if available to a grower) to completely remove salts from the soil. However, artificial drainage systems will not work where there is no saturated condition in the soil

Grape rootstocks Dogridge and 1613 has been found to be more tolerant to saline water irrigations. These rootstocks tolerated salinity by exclusion of chloride. Field studies showed that the cultivar Thompson Seedless was more sensitive to chloride toxicity than the others. Mango rootstock „Bappakai" was found to tolerate salinity levels of upto 5.3 dSm-1. More than 18 accessions of guava were screened for salt stress conditions upto 8.0 dSm-1. Accessions like *Psidium nidle* and *Psidium catellianum* could withstand the stress with 15-25 per cent mortality while other cultivars exhibited 50 per cent and more. Among fruit crops tested, guava tolerated highest salinity and can be used in saline soils. Salt tolerance studies in citrus showed that Kagzi lime was highly sensitive to salinity of even 2.0 dSm-1, whereas rootstocks like Rangpur lime and Cleopatra mandarin were tolerant. Further, Gundur, Tenali & Local acid lime cultivars were compared for their performance under salt stress and Tenali was found to perform extremely well upto 4.6 to 5.0 dSm-1 with 10 per cent reduction in yield. Soil salinity values ranged from 1.5 to 3.5 dSm-1 in these red soils. Major impact of salinity in the nutrition of acid lime was reflected in K values which reduced from 2.4 to 1.7% yield/tree in Tenali was 19.3kg under salt stress while sensitive varieties reduced as low as 6.6kg. Salinity stress can be effectively overcome by use of proper rootstocks and varieties. There are large number of resistant/tolerant varieties and rootstocks available in fruit crops which can be grown profitably under conditions of high salinity soil conditions (Table 3).

Crop residue at the soil surface reduces evaporative water losses, thereby limiting the upward movement of salt (from shallow, saline groundwater) into the root zone. Evaporation and thus, salt accumulation, tends to be greater in bare soils. Fields need to have 30 percent to 50 percent residue cover to significantly reduce evaporation. Plastic mulches used with drip irrigation effectively reduce salt concentration from evaporation. Sub-surface drip irrigation pushes salts to the edge of the soil wetting front, reducing harmful effects on seedlings and plant roots.

An early-season application of good quality water, designed to fill the root zone and leach salts from the upper 6 to 12 inches of soil, may provide good enough conditions for the crop to grow through its most injury-prone stages.

Table 5: Salinity Resistant/ Tolerant Varieties/ Rootstocks in Various Fruit Crops

Crop	**Rootstock or variety**
Citrus (*Citrus* spp.)	Rangpur lime, Cleopatra mandarin, Rough lemon, tangelo, sour orange, Sweet orange, citrange
Stone fruit (*Prunus spp.*)	Marianna, Lovell, Shalil, Yunnan
Avocado (*Persea americana* Mill.)	West Indian, Mexican
Grape (*Vitis* spp.)	Salt Creek, 1613-3, Dog Ridge
Grape	Thompson Seedless, Perlette, Cardinal, Black rose
Berries	Boysenberry, blackberry, Indian Summer raspberry
Strawberry	Lassen, Shasta

Salts are most efficiently leached from the soil profile under higher frequency irrigation (shorter irrigation intervals). Keeping soil moisture levels higher between irrigation events effectively dilutes salt concentrations in the root zone, thereby reducing the salinity hazard. Most surface irrigation systems (flood or furrow systems) cannot be controlled to apply less than 3 or 4 inches of water per application and are not generally suited to this method of salinity control. Sprinkler systems, particularly center-pivot and linear-move systems configured with low energy precision application (LEPA) nozzle packages or properly spaced drop nozzles, and drip irrigation systems provide the best control to allow this type of salinity management.

Technologies and Orchard Management Strategies to Address Climate Change

i. Developing simple and robust scientific tools that can guide the decision-making of farmers on a seasonal and long-term basis is essential for planning strategies to address climate change.
ii. In terms of risk management, some of the most relevant technologies relate to weather forecasting and early warning systems. The improved timing and reliability of seasonal forecasts and hydrological monitoring enables farmers to make better use of climate information, take pre-emptive actions and minimize the impact of extreme events (Faurès *et al.*, 2010; Gommes *et al.*, 2010).
iii. In modern commercial horticulture production systems, weather stations often monitor irrigation in accordance with the water requirements of crops. In this way, the irrigation is automatically adjusted to changes in climate.
iv. Information and communications technologies can also support the exchange of information that is needed to respond adequately to climate change.
v. Using quality seeds and planting materials, including rootstock and scion combinations, of well-adapted varieties is good agricultural practice and is climate-smart.

vi. Choosing crop species and varieties adapted to the prevalent or expected impacts of climate change for the given region and farming system is the most economical and environmentally friendly means of safeguarding crops against abiotic and/or biotic stresses, such as climate-driven extreme weather events and upsurges in pests and diseases. Useful traits include time to ripening, early and late maturity, blooming, and resistance to pests and diseases.
vii. Newly introduced crops and/or their varieties must be relevant to farmers, and farmers must know how best to grow them.
viii. To identify horticultural cultivars and cropping practices adapted to local requirements and environmental conditions, FAO has developed and maintains the HORTIVAR database.
ix. Promoting intra- and inter-specific diversity over space (e.g. intercropping, using crop variety mixtures) and/or time (e.g. crop rotations) increases the stability of crop yields.
x. Crop associations and rotations designed for specific adaptation goals use cover crops to partially or entirely replace mineral fertilizer inputs, and/or mechanical soil tillage. In climate-smart systems, the main function of cover crops is not necessarily seed production. Cover crops need to be terminated when appropriate to achieve the agronomic goal they are designed for.
xi. When including cover crops in the crop rotation, farmers must 'adjust' the cover crops to fit into the already-existing cropping system, rather than accommodating the farming system to the cover crops.
xii. Growing a single crop, using a mixture of appropriately chosen genotypes of a given species, such as a mixture of high-yielding hybrid varieties and traditional varieties, increases the producer's resilience in the face of climate unpredictability.
xiii. Growing annual crops (e.g. leguminous crops) in the rows between perennial crops requires the accurate selection of species to avoid competition for water in the most vulnerable phenological stages.
xiv. The proper interpretation of reliable seasonal forecasts allows farmers to: Plan the timing of husbandry operations, such as irrigation; pruning to avoid damage from heat or moisture; fruit thinning to balance excessively high rates of fruit set and reduce competition for developing fruit in case of excessive flowering; protecting early bloom from late frosts through short-term interventions.
xv. Inducing flower by spraying or by irrigation is a short-term intervention to break dormancy when natural climate phenomena for breaking dormancy are absent.
xvi. Protecting crops with mulch of different materials and colours, for controlling weeds and reducing evapotranspiration; nets, for bird control, insect proofing, hail protection and shading; floating mulch for protection against late frost and insects; greenhouses of different types, sizes, and different covering materials (e.g. glass, polyethylene, ethylene vinyl acetate) Greenhouses are mainly used to grow vegetables, flowers and condiments, but simple covered structures are also used to protect fruit crops like grapes for early or late harvest (e.g. in Sicily and Puglia, Italy); peach trees (e.g. in Liguria, Italy); Mango (e.g. in Egypt); and banana (e.g. in Morocco).
xvii. Integrating nitrogen-fixing perennial woody species (e.g. *Cajanus cajan* or pigeon pea) and trees with annual crops increases soil fertility, produces biomass and reduces soil erosion. This practice also sequesters carbon and redistributes the carbon to deeper soil layers.

Conclusion

Climate change and variability will affect horticulture system substantially, requiring orchardists to adapt at the same time that they are called on to reduce emissions at the orchard level. Choosing effective adaptation and mitigation strategies will represent a key challenge for farmers over the coming decades. Optimal strategies are those that, *via* careful orchard management, maintain or increase the resilience and stability of production systems, while also sequestering soil carbon and/ or reducing fluxes from farm activities. Although many positive interactions have been identified, it is important to note that synergies will not be possible under all climate and socio-economic scenarios, and across regions. Finally, improving responses to climate variability and change is a crucial requirement for future fruit production sustainability. The challenge for the field of climate change impacts on orchards including the design of appropriate adaptation and mitigation solutions is to integrate insights from the physical, bio-physical and social sciences in to comprehensive understanding of climate-agriculture interactions at seasonal to interannual and decadal to century timescales, as well as at regional and global spatial scales. The ultimate challenge is to apply this knowledge to "real-world" orchard practices and planning world wide, so the long-term sustainability may be effectively enhanced under climate change, by finding the optimal synergies between the necessary adaptation and mitigation strategies. To mitigate the adverse effects of climate change on the production and quality of horticultural produce, strategic and technological counter measures should be developed, as well as adaptation technologies against increased temperature and other climatic abnormalities. In addition, a more reliable and accurate impact assessment of climate change in its nature, degree of severity; duration and pattern on of orchard management must be established.

References

Anderson P C, Lombard P B and Westwood M N 1984. Leaf conductance. growth and survival of willow and deciduous fruit tree species under flooded soil conditions *Amer Soc Hort Sci* 109 :132-38.

Anonymous 1989. Biannual Report Fifth National Workshop on Arid Zone Fruit Research .GAU,Sardarprushinagar 6-9 July.

Atkinson C J ,Policarpo M,Webster A D and Kunden A M 1998. Drought tolerance of apple rootstocks : production and partitioning of dry matter . *Plant and Soil* 206: 223-35.

Auffhammer, M., Ramanathan, V., Vincent, J. R., 2011. Climate change, the monsoon, and rice yield in India. *Climate Change*, 111 (2), 411–424.

Aulakh P S and Sur H S 1999. Effect of mulching on soil temperature, soil moisture, weed population, growth and yield in pomegranate. *Prog Hort* 31 :131-33.

Balogoun I, Ahoton E L, Saïdou A, Bello O D, Ezin V. 2016. Effect of climatic factors on cashew (*Anacardium occidentale* L.) productivity in Benin (West Africa). *Journal of Earth Science and Climatic Change*, 7: 329.

Camelatto D and Nachtigall G R 1998. Overcoming dormancy in apple cv. Gala with mixtures of thidiazuron, hydrogen cyanide and mineral oil ,with or without calcium nitrate. *Agropecuaria-Clima Temperato* 1 :253-66.

Chaplin C E , Schneider G W and Martin D C 1974. Rootstocks effect on peach tree survival on a poorly drained soil . *Hort Sci* 9 -28-29.

Connell, N. V. and Snyder, R. L. 1999. Cover crops, Mulch lower night temperatures in citrus . *California Agriculture* 53: 37-40.

Cultar A J ,Saleem M , Kendal E , Gusta L V , Georges F and Fletcher G L 1989. Inter flounder antifreeze protein improves the cold hardiness of plant tissue. *J Plant Physiol.* 135 : 351-54.

Das, D. K., Chaturvedi, O. P., Jha, R. K. and Kumar, R. 2011. Yield, soil health and economics of aonla (*Emblica officinalis* Gaertn.; cv. NA-7) based agri-horticultural systems in Eastern India. *Current Science*, 101: 6.

Deckers T and Schoofs H 2001. First experiences with the frostbuster to protect aganist frost in orchards. *Fruitteelt-nieuws* 14 : 6-11.

Durner E F and Gianfagnan T J 1991. Ethephon prolongs dormancy and enhances supercooling in peach flower buds. *J Amer Soc Hort Sci* 116 : 500-06.

Faures, J. M., Bernardi, M. and Gommes, R. 2010. There is no such thing as an average: how farmers manage uncertainty related to climate and other factors. *International Journal of Water Resources Development*, 26 (4): 523-542.

Fernandez R T ,Flore J A and Ystaas J 1998. Intermittent application of CaCl2 to control rain cracking of sweet cherry. *Acta Hort* 468 : 683-89.

Frakulli F ,Voyiatzis D G and Metzidakis I T 1999. The growth retardents paclobutrazol and triapenthenol affect water relations and increase drought resistance of olive (*Olea europaea* L.) *Acta Hort* 474: 472-80.

Fussel, H. 2007. Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. *Sustainability Science*, 2 (2), 265–275.

Gal, A., Vyn, T.J., Micheli, E., Kladivko, E.J. and Mcfee, W.W. 2007. Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled-zone sampling depths. *Soil and Tillage Research*, 96: 42-51.

Gao D S ,Xia N and Wang X A 1999. Changes of carbohydrate content and effect of exogenous growth substances on dormancy breaking during the dormancy period of peach shoots . *Pl Physio Communication* 35 :10-12.

Gommes, R., Acunzo, M., Baas, S., Bernardi, M., Jost, S., Mukhala, E. and Ramasamy, S. 2010. *Communication approaches in applied agrometeorology*, In K. Stigter, eds. Applied Agrometeorology. Heidelberg, Springer. pp 263–287.

Guerriero R and scalabrelli G 1988. Several trails for delaying bloom in stone fruits trees by SADH. *Acta Hort* 89 :213-17.

Gupta, O. P., Arora R. K. and Chundawat B. S. 1978. Variations in the extent of winter injury in different cultivars of sweet orange on various rootstocks . *Haryana J Hort Sci* 7: 112-15.

Gur A ,Mizrahi Y and Samish R M 1976. The influence od root temperature on a apple tree II. Clonal difference in susceptibility to damage caused by supraoptimal root temperature .*J Hort Sci* 51: 195-202.

Harmon, F. N. and Synder, E. 1963. Effect of high temperature on sultanina grape on four rootstocks. *J American Society Horticultural Sciences.* 101:91-94.

Hazarika T K. 2013. Climate change and Indian horticulture: opportunities, challenges and mitigation strategies. *International Journal of Environmental Engineering and Management,* 4(6): 629–30.

Hoffman A. A. and Sgro C. M. 2011. Climate change and evolutionary adaptation. *Nature,* 470: 479–85.

Holubowicz T,Cummins J N , Forsline P L 1982. Responses of *Malus* clones to programmed low temperature stresses in late winter. *J Amer Soc Hort Sci* 107 : 492-96.

Howard C ,Weaver E and Alspach P 1998. Calcium chloride application to reduce rain splitting in sweet cherries. *Orchardist* 71 : 26-28.

IPCC (Intergovernmental Panel on Climate Change). 2007a. Climate change 2007: synthesis report. Cambridge, UK, and New York, NY: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2007b. Climate change 2007: Working Group II: impacts, adaptation and vulnerability. Cambridge, UK, and New York, NY: Cambridge University Press.

Joolka N K ,Busherhni T R and Bhutani V P 1991. Effect of growth regulators,urea and tree spray oil on bloom delay and productivity of almonds. *Indian J Hort* 18 : 217-21.

Kaynas N, Kaynas K,Burak M, Kunden A B and Dennis F G 1997. Drought resistance of Granny Smith and Amasya apple cultivars grafted on different rootstocks. *Acta Hort* 441 :255-59.

Korenberg H G 1990. Growing potentials of 'Cox's Orange Pippin' apples in Euorpe . *Scientia Hort* 42: 225-31.

Kriticos, D.J., Sutherst, R.W., Brown, J.R., Adkins, S.W. & Maywald, G.F. 2003. Climate change and the potential distribution of an invasive alien plant: Acacia nilotica spp. indica in Australia. *Journal of Applied Ecology*, 40: 111-124.

Kumar. R, and Kumar, K. K. 2007. Managing physiological disorders in litchi. *Indian Horticulture*, 52: 22–4.

Lobell, D. B., Sibley, A., Ivan Ortiz-Monasterio, J. 2012. Extreme heat effects on wheat senescence in India. Nat. *Climate Change*, 2 (3), 186–189.

Lombard P B and Westwood M N 1987. Pear rootstocks .In R C Rom and R F Carlson (eds) Rootstocks for fruit crops.Wiley,New York. Pp 143-83.

Lu and Zhao C Z 1998. Studies on covering straw- mulching of orchard in arid desert area. *Advances in Horticulture* 2 : 246-49.

Maskrey, A., Buescher, G., Peduzzi, P., Schaerpf, C., 2007. Disaster Risk Reduction: 2007 Global Review. Consultation Edition. Prepared for the Global Platform for Disaster Risk Reduction First Session, Geneva, Switzerland, pp. 5–7.

Masoud A. A. B. 2012. Impact Of Some Antitranspirants On Yield And Fruit Quality Of Hamawy Apricot Trees Grown In Sandy Soils. *Research Journal of Agriculture and Biological Sciences*, 8(2): 78-82

Mee T R 1987. Man made fog for freeze protectionand microclimate Control. International Society of citriculture : Proceedings of the international society of citriculture . 1: 203-208.

Menhenett R 1979. Effect of growth retardents ,gibberellic acid and Indole-3-acetic acid on stem extension and flower development in pot chrysanthemum, *Ann Bot* 43 : 305-18.

Meryman H T and Williams R J 1985. Basic principles of freezing injury to plant cells : natural tolerance and approaches to cryopreservation. In :K K Kartha (Ed.) Cryopreservation of plant cells and organs. *Bocalaton*13-48.

Naor A, Naschitz S,Peres M and Gal Y 2008. Responses of apple fruit- size to tree water status and crop load. *Tree Physiol* 28 :1255-61.

Okie W R 1987. Rootstocks for fruit crops. Rom R C and R F Carlson (Eds) : 321-60.

Pareek O P and Sharma S 1993. Under utilized fruits. *Indian Hort* 38 : 47-56.

Peikova I and Stankova P 1990. Study of the resistance of strawberries to low temperature .*Rasteniev'dni-Nauki* 27 :82-86.

Percival D. C.,Eaton L. J.,Stevens D. E. ,Prive J. P. and Hepp R. F. 2002. Use of windbreaks in lowbush blueberry (*Vaccinium angustifolium* Ait) production . *Acta Horticulturae*, 574 :309-16.

Petre, B. 1987. *Cercetari Agronomice in Maldova* 20:107-12.

Porlingis I C ,Voyiatzis D G and Metzidakis I T 1999. Paclobutrazol decreases the harmful effect of high temperatures on fruit set in olive trees. *Acta Hort* 474 :241-44.

Prakash G S, Bhatt R M and Narendra H K 2001. Physiological response of grapevine rootstocks cultivars to moisture stress. *Indian J Hort* 58 : 321-27.

Pyke N B ,Ansell K A and Ruth J E 1988. Field evaluation of insulation wraps for frost protection of kiwifruit trunks. *NewZealand J Expt Agric* 16 :129-135.

Rajan S, Tiwari D, Singh V K, Saxena P, Singh S, Reddy Y T N, Upreti K K, Burondkar M M, Bhagwan A and Kennedy R. 2011. Application of extended BBCH scale for phenological studies in mango (*Mangifera indica* L.). *Journal of Applied Horticulture*, 13: 108–14.

Ramaswamy N and Vijay Kumar M. 1992. Studies of the effects of flowering and fruiting behaviour of south Indian mango cultivate. (In) Fourth International Mango Symposium, Miami Beach, FL 47.

Rangaswami, G and Mahadevan, A. 2002. Diseases of crop plants in India. .*Prentice-Hall of India Pvt Ltd. New Delhi, India* pp 322.

Rehman E A 2010. A study on some treatments which mitigate drought effects on Barrani grapevines cv. *J Appl Sci Res* 6 : 704-711.

Rosnadze G R,Mikaberidz V E and Goguadze R S 1989. The effect of chloromequat (TUR) on the growth and frost resistance of lemon trees. *Subtropicheskie Kultury* : 60-68.

Salem A T M 1991. Waterlogging tolerance of three citrus rootstocks. *Bulletin of Faculty of Agric Univ Cario* 42 :881-94.

Sankhla N , Sankhla D, Upadhyaya A and Davis T S 1989. Amelioration of drought and high temperature injury in fruits of ber by paclobutrazol .*Acta Hort* 239 :197-202.

Sharma D. R., Arora, P. K. and Singh, S. 2005. Insects and mite pests of fruit crops in Punjab :A survey report. *Journal of Plant Science and Research,* 21: 109-115.

Sharma, V. K. 2015. Climate change and its impacts: understanding some facts, myths, and controversies. In: Mahendra Dev, S. (Ed.), India Development Report 2015. Oxford University Press, New Delhi, pp. 271–282.

Sherman W G, Lyrane P M and Andrews C P 1986. Proceedings of the Tropical Region . *Amer Soc Hort Sci* 23 :25-28.

Singh R N, Majumder P K and Sharma D K. 1966. Sex expression in mango (Mangifera indica L.) with reference to prevailing temperature. *Proceedings of American Society Horticulture Science,* 89: 228.

Steffens G L, Stutte G W and Cooke A R 1988. Thidiazuron substitution for chilling requirement in three apple cultivars . *Proc of Plant Growth Regulators Soc of America* :65.

Steinberg S L ,MeFardland M J and Worthington J W 1990. Antitranspirants reduces water use by peach trees following harvest. *J Amer Soc Hort Sci* 115 : 20-24.

Strang J C and Stushnoff C 1975. A classification of hardy North American apple cultivars based on hardiness zones.*Fruit Var J* 29 :78-108.

Vashishtha B B 1999. Horticulture based agro-forestry system for the management of problematic soils of arid region. Short course on sustainable rehabilitation of degraded land through agroforestry.*National Research Centre for Agroforestry Jhansi*:132-35.

Ventura P G 2000. A new system for protecting fruit trees from late frosts . *Informatore Agrario* 56: 90-91.

Wang, C E , Schneider G W and Martin D C 2007. Rootstocks effect on peach tree survival on a poorly drained soil . *Hort Sci* 9 -28-29.

Wolfel D and Noga G 2000. Effect of alpha-tocopherol and glycerol on the prevention of frost injury to flowers of fruit trees. *Fruit Belge* 68 :165-69.

Yelenosky G and Hearn C J 1977. Cold damage to young mandarin-hybrid trees on different rootstocks inflatwood soil.*Florida State Hort Soc* :53-56.

Young E and Reid B O 1989. Siberian C rootstocks delays bloom of peach. *J Amer Soc Hort Sci* 104 :178-181.

Zhuang, J., 2009. The Economics of Climate Change in Southeast Asia: A Regional Review. Asian Development Bank, Manila, Philippine.

Zibberstaine M, Herzog Z ,Doron Y,Monol M T and Saygili H 1999. Removal of off-season flowers in order to avoid *Erwinia amylovora* infection in pears. *Acta Horticulturae,* 489 : 625-28.