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Impact of climate change on fruit production and various approaches to mitigate these impacts

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Abstract
Climate change and agriculture are interrelated in a number of ways as climate change is the main cause of abiotic and biotic stresses which have harmful effects on the agriculture. Raising temperatures, drought or water stress, changing climate zones, rainfall, insect- pest outbreaks etc are the major consequences of climate change. The impact of climate change on fruit crops is likely to be more detrimental as compared to field crops as the adaptation capacity of shorter duration crops is generally greater than perennials. Climate change affects fruit crops in their different phases of growth and development such as fruit sunburn, inadequate pollination, delayed ripening, reduced color development, low sugar content, poor fruit quality and fruit set, low fruit yield, reduced panicle emergence. Heterozygosity nature of most of the fruit trees leads in high genotype and environment interaction (G×E). So, the effect of temperature in every single crop is different. Since fruit trees are perennial in nature mitigation measures after the orchard development are difficult to implement. Therefore, by adopting the new technologies, by managing the existing technologies properly or variety selection which suits to climate change are only the key measures to overcome these effects on fruit production. In this review paper we will discuss about the impacts of climate change and various strategies to overcome these effects.

Keywords: climate change, temperature, drought, salinity, adaptation strategies

Introduction
Generally people consider climate and weather as a same phenomenon but in reality there is difference between these two. Weather is defined by measuring certain atmospheric parameters such as temperature, pressure, humidity, wind strength and direction, rainfall, heat waves, snowfall, cloud, sunshine etc. at a particular time (Kumar, 2019) [31] whereas average weather condition over a longer period of time usually about 30 years is known as climate and change in climate which has lasted for decades or longer, resulting from either natural causes or human activities known as climate change (Solomon *et al.*, 2007) [63]. It involves rising temperature, shifting in the cycle of rainfall, rising sea levels, infiltration of salt water, generation of floods and droughts etc (Bates *et al.*, 2008; Shetty *et al.*, 2013; Pathak *et al.*, 2012) [6, 60, 44]. On a global scale these changes in climate causes negative impacts on agriculture which ultimately affects the supply of food in the world (Afroza *et al.*, 2010; Pathak *et al.*, 2012) [1, 44]. Change in the climate or its variability are the major challenges that affect the production of agriculture including annual and perennial horticultural crops. Reduction in production of fruits and vegetables is likely to be caused by short growing period, which will have negative impact on growth and development particularly due to terminal heat stress and decreased water availability. Agricultural crops that are grown in the rainfed areas will be primarily affected because of variability in rainfall (Venkateswarlu and Shanker, 2012) [74].
India has diverse soils and climates in several agro-ecological regions and offers adequate possibilities to grow horticultural crops which constitute an important part of the overall production of fruits and vegetables, aromatic and medicinal plants, root and tuber crops, ornamental and flowers, spices, mushrooms and plantation crops in the country (Reddy *et al.*, 2017) [58]. To measure the effects of climate changes on crops we must have adequate information on their physiological responses, effects on productivity, development, growth and quality of fruit crops. This means we must have proper knowledge about the cultivating crop either it will be suitable for this region or not. Various impacts need to be tackled in a coordinated and comprehensive way in order to plan the horticulture industry to meet the

impending threats of climate change (Malhotra, 2017) [36]. The emerging problems such as global climatic change, contamination of water and soil, limited supply of water, urbanization, etc. contribute to this situation. In combination with high temperatures, lower precipitation may reduce irrigation and raise evapo-transpiration that could lead to water stress conditions in many crops (Datta, 2013) [13]. Climate change would also impact the duration of growing seasons, livestock or crop yields, raises the risk of food shortages and the incidence of pests and diseases, placing people at greater risk for health and livelihoods (Neely *et al.*, 2009) [39]. Growing of horticultural crops plays a crucial role in the welfare of the country and in the economy of India by raising the incomes of the rural population and is directly related to the happiness or health of the people as well as generating a great deal of employment opportunities for the rural population. So, the development of horticultural crops which can tolerate stress to some extent will be the only and single main step we may take to adapt the changes which we are facing today and which we will face in the future (Datta, 2013) [13]. It is convenient and illustrative to divide fruit plants into categories based largely on temperature requirements, i.e. tropical, sub-tropical and temperate zones (Jackson *et al.*, 2011) [26].

Tropical Fruits	Subtropical Fruits	Temperate Fruits
Mango, Banana, Papaya, Pineapple, Sapota, Guava, Jackfruit, Tamarind.	Citrus, Bael, Aonla, Grapes, Pomegranate, Phalsa, Jamun, Mangosteen, Datepalm, Fig, Litchi, Karonda	Strawberry, Plum, Avocado, Pear, Walnut, Peach, Cherry, Apple, Almond

Effect of Climate Change on Horticultural Fruit Crops

It has been shown that high-chilling needed apple cultivars like Royal Delicious have been replaced with low-chilling required cultivars and other fruit crops like peach, kiwi, plum, pear and vegetables. The trend is to switch from the potato and apple cultivation fully in the middle hills of Shimla district. The snowfall pattern and apple production in Himachal Pradesh have been corroborated in this regard. Apple production fell from 10.8 to 5.8 tons per hectare. This is just an example of climate change (Awasthi *et al*., 2001) [4]. Many abiotic factors are arises due to change in climate which consequently effects the several horticultural fruit crops and their physiological, anatomical, morphological & bio-chemical parameters. Environmental factors, such as temperature, drought, salinity, flooding, rise in CO_2 concentration, and outbreak of insect-pests, have the greatest effect on fruit production (Gora *et al.,* 2019) [20].

I. Temperature

A high temperature alters plant morphology, anatomy and physiology, affecting seed germination, plant development, flower shedding, pollen viability, gametic fertilization, fruit setting, fruit weight, size and fruit quality (Gora *et al.*, 2019) [20]. Many fruit crops are severely affected due to hot and cold waves (Malhotra, 2017) [36]. In perennial fruit crops such as mango temperature affects flowering. Mango has a vegetative tendency and when temperature rises it bears more number of leaves thus impacting the phenology of flowering. It may be noted that the hermaphrodite flowers (having both stamen and carpel) percentage in late emerging panicles was higher which also coincided with extreme temperatures (Balogoun *et al.*, 2016; Singh *et al.*, 1966) [5, 62]. In bearing or non-bearing trees of mango, scorching of leaves and the dying of twigs are the main symptoms of heat stroke. In mango, the major effects observed during climate change were multiplication of reproductive flushes, early flowering or delayed flowering, poor fruit set, reproductive buds transformation into vegetative ones, changes in the fruit maturity etc (Rajan *et al*., 2011) [54]. In hot & humid situation, the incidence of insect-pests and diseases are more in fruit crops like in Guava the attack of Fruit fly is more in such conditions, in Papaya Leaf curl virus attack is also more whereas the crops like apricot, plum or peach which needs low chilling temperature shows the sign of decline in productivity due to such extreme temperatures (Hazarika, 2013) [23]. In general, higher temperature of 31-32 ºC increases the maturity rate in banana plant thus shortens the period of bunches development (Turner *et al*., 2007) [72]. High temperature of more than 38 ºC cause choking of bunches in banana (Stover, 1972) [67].

Although the grape originated in temperate regions, advances in production method have enabled it to adjust to subtropical and tropical region. Availability of growing degree-days (GDD)/temperature under climate change will lead to speeding up of the phenological processes (Wolfe *et al.*, 2005; Webb *et al.*, 2007) [76, 75]. In grape wines, the development of anthocyanin is influenced by the day and night (15-20 ºC) temperatures with high variation which promotes color development. In these conditions, therefore, we will have to select those regions and varieties that are appropriate for the production of high quality fruit. Extreme temperatures for prolonged periods in grapes usually delays fruit ripening and decreases quality of fruit. Varieties will vary in temperature tolerance (Kadir, 2005) [29]. Temperature fluctuations lead to changes in stages of growth and ultimately the maturation phase of the grapes. At the period of fruit growth, fruit firmness, TSS and dry weight percentage were negative related with temperature and it also differ with cultivars (Hoppula *et al.*, 2006) [25]. No. of cluster/shoot increases with the increase in temperature but number of flower/cluster get reduced (Subedi, 2019) [68]. Higher temperatures in papaya led to flower drop in female and hermaphrodite plants and also responsible for changes in sex in hermaphrodite plants. If flowering occurs under extremely low temperatures, flower drops in papaya are relatively normal (Reddy *et al.*, 2017) [58]. In Cavendish bananas, the development of the golden yellow color is affected at high temperatures (Friend, 1981) [17]. In strawberries due to high temperatures and increased CO_2 resulted in a 12 and 35 per cent reduction in yields at low and high nitrogen level, respectively (Sun *et al.*, 2012) [69].

Extreme temperatures influences crops directly or indirectly like when the temperature is high the population of pollinating insects significantly decreased. So there is no fertilization thus impacting the fruit set.

Effect of Low Temperature

Inadequate chills can reduce pollination for cross-pollinated fruits such as pistachios and walnuts and thus reduces the crop yields. Optimum temperature in temperate fruits such as plum, apples, cherry, pears etc. for pollination and fertilization is between 20° and 25 °C. During pollination in USA in sour cherry conditions like foggy, rainy or low temperatures were found to have a negative impact (Haokip *et al.*, 2020) [22]. Horticultural crops suffer a 10-100 percent return loss which depends on the crops and varieties because of the extremely cold waves (Hazarika, 2013) [23]. In longan fruit, overwinter develops problems like severe fruit drop, reduction in fruit size and fruit cracking. In the young fruit phase temperatures of less than 15°C reduce the potential and final size of fruit growth. Stressful cold or sudden changes in temperature cause severe fruit drop. Cold or dry weather during the young fruit stage is linked to extreme fruit cracking (Yang *et al.*, 2010) [78]. The low temperature in the case of mandarins has dual effects, inducing flowering as well as breaking bud dormancy. Potential flower buds have deeper dormancy than vegetative buds and the first stages of flower initiation seem to occur before the winter rest period (Reddy *et al.*, 2017) [58]. Low temperatures, leading to low TSS, affected the acidity content in Naval oranges (Peng *et al.*, 2000) [47]. So only those crop should be grown which is well suitable for that climate. Like Papaya is very sensitive to frost thus it is not suitable under Punjab conditions. Exposure of horticultural crops to increased heat stress is the cause of physiological disorders and their associated problems (Gora *et al.*, 2019) [20]. List of important physiological disorders and their relative cause in fruit crops are as follows

List of important physiological disorders and their relative cause in fruit crops are as follows

Fruit crop	Disorders	Caused due to	References
Mango	Spongy tissue	High Temp.(Convection Heat)	Katrodia *et al.*, 1985 [30]
Aonla	Unfruitfulness	Temperature	Bhargava *et al.*, 2011 [7]
Loquat	Purple spot	Temperature	Gariglio *et al.*, 2003 [19]
Bael	Fruit cracking	Deficiency of Nutrients	Saini *et al.*, 2004 [59]
Citrus	Granulation	Water moisture	Zong *et al.*, 1979 [80]
Mango	Black tip	Harmful Gases like CO and SO2	Zhang *et al.*, 1995 [79]
Mango	Fruit drop	Lack of pollination	Pandey, 1998 [42]
Mango	Jhumka	Lack of pollination	Negi, 1999 [40]
Pomegranate	Fruit cracking	Variation in day & night temp.	EI-Rhman, 2010 [15]
Grape	Flower and berry drop	High temp, Lack of pollination	Jawanda *et al.*, 1974 [27]

Source: (Mishra *et al*., 2016)

II. Drought

Drought occurs frequently in arid and semi-arid climates with uneven precipitation and it refers to as lack of precipitation (Kumar *et al.*, 2019) [32]. In phenological phases, water stress can be very critical to the yield response and is very important in planning irrigation within significant water limit areas (Jones, 2004) [28]. Stress prior to or during the flowering and post-blooming periods in perennial fruit plants has negative impact on yields through lower numbers of fruits and cell reduction of remaining fruit (Powell, 1974; Powell, 1976) [50, 51]. Drought severely affects growth, yield and productivity of banana by reducing photosynthetic capacity of the plants. During the period of finger development lack of adequate water induces shortening of bunches (Surendar *et al.*, 2013) [70]. African banana production losses mainly result due to the water deficit, in particular because of a negative impact on the intake of nutrients (Van *et al.*, 2011) [73]. In bananas, drought stress reduces finger numbers during floral initiation (Holder and Gumbs, 1983) [24], while after emergence it contributes to poor filling (Mahouachi, 2007) [34]. It has been noted that moisture stress decreases the size and number of fruits in tomato. In the extremely stressed plants the occurrence of blossom end rot and sunscald was higher. TSS content was influenced significantly by irrigation treatments and it increases with stress level while the water content of fruit was decreased (Birhanu and Tilahun, 2010) [8]. In avocado, during flowering and fruit development long-term water stress situation lead to fruit and flower drop (Paull and Duarte, 2011) [46]. Plants with a low water capacity in sandy soils are more prone to drought stress condition than plants which grow in clay soils (Ogbaga *et al.*, 2014). A plant with high leaf mass is more prone to water stress than the water source from the roots as leaves loses water easily. In the initial stages, due to the poor development of root system and growth of foliage is high the newly established orchards are more prone to drought stress (Kumar *et al.*, 2019) [32].

III. Rainfall

Rainfall is also another major factor which arises due to climate change. Uneven precipitation or no rainfall decreases the crop yield especially in the rainfed areas. Heavy rainfall in the areas of poor drainage causes oxygen availability in soil which leads to the killing of growth of beneficial microorganisms and due to water logged conditions many insect-pests and diseases occurs which will affect crop yield. Modifications in the patterns of precipitation may adversely affect the appearance and quality of mature mango fruits. At the time of flowering rainfall adversely affect the fruit set, growth and yield. In certain areas, because of prolonged and heavy precipitation excessive vegetative growth and flower drop occurs. Untimely rains influence pests resulting poor fruit yield (Makhmale *et al.*, 2016) [35]. In the regions of high rainfall, fruits at maturation period are exposed to various diseases such as anthracnose in mango fruit (Ploetz, 2003) [49]. Rain during flowering wash out the pollen from stigma of flower resulted to poor or no fruit setting. Mango production loss 80- 90 % was reported in Gujarat due to unseasonal rain followed heavy dew attack which reduced fruit setting, increased fruit drop and also increased heavy incidence of sooty mould and powdery mildew in mango (Rajatiya *et al.*, 2018) [55]. Another aspect to consider in fruit species growth is the low availability of oxygen due to excess water. The normal precipitation cycle, flooding arable land and agricultural crop production have been affected by climate change. Throughout this way, extended water stress cycles will lead to losses from yield between 10% and 40%. Water-logging cycles of more than two days in Cape gooseberry are beginning to lower the leaf area. After four days of exposure, the stem diameter is smaller. Hence, bud initiation, fruits and flowers get reduced with extreme stress (Aldana *et al.*, 2014) [3].

IV. Carbon Dioxide

The CO_2 level is one of the most limited factor in terms of fruit growth due to the high emission level (Swaminathan and Kesavan, 2012) [71]. The increasing concentration in atmosphere would have a great impact on determining the fruit productivity since carbon dioxide is an important element for photosynthesis (Ramirez and Kallarackal, 2015) [56]. The increased concentration of carbon dioxide in the air around the leaf blade lowers the stomatal conductance, stomatal aperture and transpiration; subsequently growth and photosynthesis increase due to high water use efficiency (Stöckle *et al.*, 2011) [66]. High level of CO_2 requires high amount of water and fertilizers resulting increase in growth. Since more nitrogen is required to ensure high productivity in climate change conditions (Ramirez and Kallarackal, 2015) [56].

Beneficial Impacts of Climate Change

Increasing temperature and CO_2 level in atmosphere except negative impact they are also benefited to some crops. Like, the photosynthesis rate of C_4 plants was increase as compared to C_3 plant with an increasing temperature (Yamori *et al.*, 2014) [77]. It was observed, however, that the concentration of CO_2 in C_4 plants is saturated rapidly, while photosynthetic response rates in C_3 species continue to rise in several hundred ppm of CO_2 across this period (Roggers *et al.*, 1994). Floral initiation of mango trees is mainly controlled by low temperatures. As a result, rising temperatures will adversely affect flower initiation. However, in regions with relatively low temperatures during flowering, growing temperatures will have a positive impact on the viability of pollen and fruit set (Dambreville *et al.*, 2014) [12] and also on the growth of mango fruits, which would be faster. The warm and dry period in pomegranate during the development increases the proline accumulation of fruit. So, climate change may also improve the quality of certain fruit crops (Halilova *et al.*, 2009) [21]. According to the NPCC report, the temperate zone farmers was benefited by the climate change as the temperature increases of apple belt to 30 kilometers upwards (north). Therefore, new apple orchards have been developed in Lahaul & Spitti and the upper reaches of Kinnaur district of Himachal Pradesh, which were previously not appropriate for them and farmers in lower zone moved from cultivation of apple towards pomegranate, kiwi or other fruits and vegetables (Rajatiya *et al.*, 2018) [55]. Climate change allows lower-altitude crops to thrive at greater heights, but before we substitute the old crop for the new one, we must consider the cost-benefit analysis (Mathur *et al.*, 2012) [37].

Table 1: Effect of Climate Change on Fruit Nutritional Quality

Fruit crop	Climate variable	Nutritional quality variable	Observations	References
Apple	Humidity, Temperature and solar radiation	Sugar-acid ratio, Anthocyanin and Vitamin C content	Rising temperatures and decreased sunshine have increased the apple's nutritional quality by increasing the concentration of anthocyanin, the vitamin C content and the sugar-acid ratio.	Qu and Zhaou, (2016) [52]
Banana	Rainfall, Temperature and solar radiation	Carbohydrate content and concentrations of Micronutrient	As average daily temperature increased, the average fruit weight and fruit content decreased and P, Mg and Ca levels increased. There were different effects on these quality variables of rainfall, temperature and soil type.	Bugaud *et al.*, (2009) [10]
Grape	UV and Sunlight exposure	Anthocyanin, total phenolic and tannin content	The anthocyanin, total phenolic and tannin content of wine are also increased as UV exposure and sunlight exposure for grapes increases.	Song *et al.*, (2015) [64]
Grape	Rainfall and Temperature	Phenolic and Anthocyanin content	The content of anthocyanin and phenolic in grapes showed negative correlation to rising temperatures. Temperature has increased effects on phenolic contents if the rainfall is lower than normal.	Fourment *et al.*, (2017) [16]
Citrus (Orange)	Soil salinity	Content of micronutrients in leaves	The micronutrients conc. in the leaves of sour orange on different rootstocks varied as the soil salinity increased. Like Na^+ and N conc. increased, while Ca^{2+}, K^+, Mg^{2+} conc. decreased and P conc. did not change.	Garcia *et al.*, (2002) [18]
Citrus (Orange)	Frost	Proteomic and metabolic profiles	The frost has impacted protein levels, primary and secondary metabolites. Because of the frost, there has been increased expression of some components of the fruit, decreased expression of others and varied as time went by after freeze.	Perotti *et al.*, (2015) [48]

Source: (Stewart and Ahmed, 2020) [65]

Strategies to Overcome the Effect of Climate Change

Adaptation is the mechanism by which farmers reduce the negative impacts of climate change and adaptation measure means to protect the environment against the anticipated impact of climate change. Understanding the impacts and related adaptation strategies are of the utmost importance to maintain the productivity and profitability of horticultural crops in the evolving climate scenario which includes a synthesis of current knowledge to establish adaptation and mitigation strategies for climate-resistant horticulture (Lal *et al.*, 2018) [33].

Crop Improvement Strategies

Diversification

Diversification is an effective technique used to reduce the effect of climate change. A single crop can give heavy production under favorable climatic conditions, but diversity can add stability to the production system, minimize disease and infestation of pests. In order to overcome the uncertainties and variations in growth, farming communities around the world use a diversified crop system and fruit trees provide valuable opportunities to diversify crops. Diversification with fruit crops such as olives, kiwi, peach, walnut and apricot (Subedi, 2019) [68].

Development of genotypes having resistance to drought, salinity, moisture stress, insect-pests and diseases.

Varieties/Rootstock Tolerant to Drought

Table 2: Resistant rootstocks and varieties of fruit crops should be selected (Malhotra, 2017) [36]

Fruit crop	Rootstock/Variety	Trait
Guava	*Psidium cujavilis*	Tolerant to drought
Citrus	Rangpur lime	Tolerant to drought
Sapota	Khirni	Tolerant to drought
Ber	*Ziziphus nummularia*	Tolerant to drought
Ber	*Ziziphus rotundifolia*	Tolerant to drought
Passionfruit	*Passiflora incarnata*	Tolerant to drought
Pomegranate	Ruby	Tolerant to drought
Annona	Arka Sahan	Tolerant to drought
Cherry	Mahaleb	Tolerant to drought
Fig	Deanna, Excel	Tolerant to drought
Grape	110R, Dogridge	Tolerant to drought

Source: (Singh *et al*., 2009; Bose *et al*., 2001) [61, 9]

Table 3: Varieties/Rootstock Tolerant to Salinity

Fruit crop	Rootstock/Variety	Trait
Grape	110R, Dogridge	Tolerant to salinity
Mango	Nileshwar dwarf, Kurukkan	Tolerant to salinity
Citrus	Cleopatra mandarin	Tolerant to salinity
Fig	F. glomerata	Tolerant to salinity
Mango	Bappakai	Tolerant to salinity
Lime	Rangpur lime	Tolerant to salinity

Source: (Singh *et al*., 2009) [61]

Table 4: Varieties/Rootstock Tolerant to Moisture Stress

Fruit crop	Rootstock	Trait
Apple	MM 111	Tolerant to Moisture stress
Sapota	Khirni (*Manilkara hexandra*)	Tolerant to Moisture stress
Pear	Pyrus betulaefolia and Pyrus calleryan	Tolerant to Moisture stress
Fig	Gular (Ficus *glumerata*)	Tolerant to Moisture stress
Almond	Prunus xerophila and P. amygdaliformis	Tolerant to Moisture stress
Guava	Psidium cujavillis	Tolerant to Moisture stress
Citrus	Alemow, Swingle	Tolerant to Moisture stress
Ber	*Ziziphus rotundifolia and Z. nummularia*	Tolerant to Moisture stress

Source: (Nimbolkar *et al*., 2016) [38].

Table 5: Varieties/Rootstock Tolerant to Insect-Pest and Diseases

Fruit crop	Rootstock/Species	Trait
Guava	*Psidium molle × Psidium guajava*	Wilt resistant rootstock
Guava	*Psidium friedrichsthalianum*	Nematode tolerant rootstock
Fig	Ficus glomerata	Nematode tolerant rootstock
Passionfruit	*Passiflora alata*	Fusarium wilt tolerant
Citrus	Rangpur lime	Phytophthora tolerant
Avocado	G_6 selection (Mexican)	Phytophthora root rot tolerant
Avocado	Duke 7, D9, Thomas and Barr-Duke	Phytophthora root rot tolerant

Source: (Singh *et al*., 2009) [61]

Table 6: Introduction of Pome, Nut and Stone Fruits Having Low Chilling Requirement

Fruit crop	Low chilling cultivars	Chilling requirement
Apple	Michel, Tamma, Anna, Vared, Schlomit, Tropical Beauty, Mayan	Less than 800
Plum	Satluj purple, Santa Rosa, Alubokhara, Kala Amritsari, Jamuni, Titron.	Between 150 and 300
Peach and nectarin	Flordasun, Nectarine, Sharbati, Sunred, Sun Gold, Shan-e-Punjab, Saharanpur Prabhat,	Less than 500
Pear	Punjab Nectar, Gola, Leconte, Patharnakh, Kiffer,	Less than 150

Source: (Rai *et al*., 2015) [61]

Strategies Based on Development of Agro-Techniques

- Development of effective agricultural adaptation steps to reduce losses in production linked to adverse climatic conditions.
- The phenology of nut, pome and stone fruits under environment changing will be monitored and accordingly the package of practices needs to be developed.
- In-situ soil moisture management activities including indigenous technological know-how are validated to minimize the effects of drought.
- Changing the date of planting and increasing the use of the integrated farming system.

- Adopting new farm techniques, resource conserving technologies (e.g. bagging of fruits, fertigation etc).
- Recycling of waste water and solid wastes in agriculture and use water harvesting technologies.
- Improve technologies for water saving
- Increased use of composts (Lal *et al.*, 2018) [33].

Use of Mulching

Mulching which conserve the soil moisture, improve soil microclimate, microbial activity and soil health. Selection of mulches is another important strategy. Like for insect repellent silver color mulch; for weed control Black film or for soil solarisation thin transparent mulch should be used. It may be noted that the plastic mulch was increased yield percentage in Papaya (64.24%), Mango (45.23%), Banana (33.95%), Ber (27.06%), Guava (25.93%), Pineapple (14.63%) and Litchi (12.61%) as compared to control (Patil *et al.*, 2013) [45] and in strawberry maximum runner plant yield observed with the treatment of white-on-black plastic mulch at warmer location (Cook, 2002) [11].

Use of Anti-Transpirants

Use of anti-traspirants like chitosane, kaolin, etc. which reflect the heat radiation from plant parts so they reduce the water losses through transpiration and reduce the temperature of fruit and leaf surface and other chemicals. The treatment with anti-traspirant chitosane at 2% gave significantly maximum average finger weight, average hand weight and bunch weight in banana as compared to rest of treatments (Ahmed, 2014) [2]. Maximum premium grade pomegranate fruits in the treatment with terra alba because it reduces the average fruit and leaf temperature as compared to control (Parashar and Ansari, 2012) [43] and kaolin is an important treatment to minimize sunburn in pomegranate fruit (Ehteshami *et al.*, 2011) [14]. Other chemicals like Bordeaux mixture was the best method for reduction of frost damages on grapes grown in moderate cold climate as compared to other frost reduction approaches (Yamori *et al.*, 2014) [77].

Establishing Windbreaks

Wind breaks or shelter belts which modified the microclimate of orchard as well as soil and windbreak also provide shelter for pollinating insects, protect orchard from wind erosion and other natural disaster, etc. The minimum mortality percentage of fruit plants affected by frost was observed in orchards of fruit crops surrounded by wind breaks (2.97 to 30.81%), whereas in the absence of these barrier led to maximum mortality (up to 91.43%) (Rathore *et al.*, 2012) [57].

Conclusion

Climate change is a fact and there is ample proof that GH gas emissions cause climate change and global warming. 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. Low winter chill affects tree behavior such as flowering and lack of uniformity. In view of the potential effect of climate change more emphasis must be given to the development of heat and drought resistant varieties. Variety selection is one of the most important process in the development of new orchard because the variety suitable for the current climate cannot be suitable for future climate conditions in the long term. At the time of orchard establishment, planting of thick and tall growing wind breaks is needed. During the summer season serious pruning of trees should be avoided. Selection of suitable rootstock is also an important factor to match the changing climatic situation. Fruit development is a long term investment. Only a few changes can be made after the orchard has been established. So, adaptation methods towards changing climate should focus on improvement of existing technologies to create a suitable production environment for current as well as future conditions.

Future Strategies

- Need to investigate the physiology, phenology, growth, yield and quality of fruit crops at high temperatures, CO2 and excessive water and water deficit stress.
- Identification and development of heat, water and climate-tolerant crops and varieties for various agro-ecological regions and growing seasons.
- Production of modern strategies that can manage chilling requirements of temperate fruit crops.
- Environmentally-friendly chemicals should be generated to break the dormancy period.
- At the time of orchard establishment, planting of thick and tall growing wind breaks is needed.
- Farmers should therefore, select those varieties that can tolerate greater stress such as heat, drought, photo and thermal insensitivity. The selected varieties should have deep root system (bael, ber), wax coating (ber), leaf shedding (pomegranate, lasoda), stem thorns (Karounda, ber), lower side stomata (custard apple), leaf orientation and thin foliage (aonla), sunken stomata and leaf hair (fig, ber, phalsa and lasoda).

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