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Impact of temperature and water on physiological and biochemical changes in fruit crops

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Abstract
Temperature and water influences the life cycle of fruit plant in a variety of manners. High temperature, low temperature water stress are the major consequences of climate change. Adverse effect of high temperature and low temperature has been noted during both vegetative and reproductive growth stages in various fruit crops. The adverse effect of temperature on fruit plants occurs when crosses its limits. These effects are either due to direct injuries or due the reduced activity of enzymes and disturbed metabolic processes. Water is required by the fruit plants throughout their life for different physiological processes. Water influences cell division, cell enlargement, respiration, absorption, translocation and utilization of mineral nutrients besides other physiological processes. Optimizing water applications by scheduling irrigation to fruit orchards may increase water productivity, reduce production costs and increase tree growth and fruit yield.

Keywords: Temperature, water, physiological and fruit crops

Introduction

Adverse environmental condition and temperature limits are significant abiotic stresses causing extreme yield misfortune in fruit crops. Environmental stresses are the primary cause of crop losses worldwide, decreasing normal yield for the significant harvests by over 50%.Heat stress is expected to become a major issue in reducing crop production in coming years due to global warming (Wahid *et al.*, 2007) [52-53]. High temperature stress disrupts the biochemical reactions fundamental to normal cell functioning and it primarily affects the photosynthetic functions of higher plants (Weis and Berry, 1988) [50]. Reproductive processes are also highly affected by heat stress in most plants (Wahid *et al.* 2007) [52-53]. High temperature causes a variety of morphological, physically and physiological and biochemical changes in the plants which influence development and improvement and may prompt the extraordinary decrease of monetary yield. Low temperature and ice adversely affect the digestion with a comparing decrease in crop quality and quantity. Low temperature stress likewise shows expanded oxidative damage in plants. There is enhancement of antioxidant defence mechanism of the plant under low temperature stress. As chilling and freezing temperature cause water deficit inside the cells the compatible solute manital, which alleviates water stress has been shown to protect chloroplastic, phosphokinase from hydroxyl radical of damage under stressfully condition (Shen, *et al.*, 1997) [39].

Eco physiology is the study of environmental effects on plant physiology; these conditions are of paramount importance for the success of any crop (Fischer and Orduz-Rodriguez, 2012) [19]. Eco physiological research is conducted to describe the physiological mechanisms during development and growth of plants that interact with physical and biotic environmental factors (Lambers *et al.*, 2008) [28].

An orchard is characterized by an environment composed of light, temperature, water, humidity, wind, various atmospheric gases, soil nutrients and other conditions of the rhizosphere. During the growth of plants several climate and stress factors are influential at the same time for the crop, such as drought, heat, UV light, etc. (Mittler, 2006) [29], *i.e.* no climatic factor alone can decide the physiological performance. For example, photosynthesis depends not only on radiation, but also on temperature, CO_2, water and nutritional elements (Fischer and Orduz-Rodriguez, 2012) [19].

To adapt fruit production to these new situations, mostly adverse to crops, a complete understanding of multiple effects of climate change on plant physiology is required (Swaminathan and Kesavan, 2012) [46].

The aim of this review paper was to elucidate how these factors, focusing on solar radiation, temperature, water and carbon dioxide, affect the physiology of the fruit plants, in general, with emphasis on fruits from the tropics and subtropics, and with some experiences of species from the temperate zones.

Water is the main contribution for natural product creation. It is expected by the fruit plants all through their life for various physiological cycles. Water impacts cell division, cell enlargement, respiration, absorption, translocation and use of mineral supplements other than other physiological process. Optimizing water applications by scheduling irrigation to fruit plant might increment water efficiency, decrease creation expenses, and increment tree development and fruit yield. Water is a constituent of cellular material and assists with keeping up with the bloat of cell divider. Plants can union food just within the sight of water in their framework through photosynthesis. It is additionally a mean of warm guideline of temperature inside the plants. Inadequate water supply might bring about diminished tree development, yield and natural product quality because of water pressure. Extreme water system, then again, may increment supplement filtering, water-logging issues, rate of vermin and sicknesses and the related expense of continuous activity and support of the water system framework. Subsequently through the ideal utilization of water, execution of plants can be further developed manifolds.

Effects of temperature incidence on fruit crops

The reproductive phase is considered as a highly sensitive stage to high temperature stress in tomato (Sato *et al*., 2000) [40]. The floral organs were most adversely affected at the initial stages of development (Wahid *et al*., 2007) [52-53]. As anthesis is the crucial stage for the determination of the productivity of the crop, heat tolerance at this stage is very important.

High temperatures

High temperatures greatly affect fruit crops, especially with poor fruit set and decreases in production. For example, in grape vine, temperatures >35 °C hinder fruit set, in cape gooseberry ≥30 °C can inhibit flowering, in mango >35 °C reduce the viability of pollen and fruit set (Fischer and Orduz-Rodriguez, 2012) [19]. Hot tissues are softer and lose their texture and, hence, resistance to attacks by pathogens and insects-pests; in addition, high temperatures cause the degradation of organic acids required primarily for the respiration of ripe fleshy fruits and make them insipid (Fischer and Orduz-Rodriguez, 2012) [19]. Also, high night temperatures greatly degrade pho-toassimilates, affecting the filling and organoleptic quality of fruits (Das, 2012; Gariglio *et al*., 2007) [13, 23].

Global warming affects photosynthesis, especially in C3 plants, *i.e.* all commercially fruit species (except the few CAM fruit species); however, this effect has been little studied. In general, in C3 fruit plants, requiring lower temperatures, heat increases photorespiration because the Rubisco in C3 plants reacts with increased oxygenation to the cost of carboxylation and therefore a lower production of biomass than C4 plants (maize, sorghum, etc.) (Pritchard and Amthor, 2005) [34]. In their review about climate change on crop plants, (Jarma *et al*., 2012) [25] concluded that high temperatures can have adverse effects on physiological processes such as photosynthesis, respiration, water relations, hormone regulation and secondary plant metabolism, as well as on membrane stability. High temperature stress induces morphological, anatomical, physiological, biochemical and genetic responses in plants (Camejo *et al*., 2005) [11], which additionally decreases crop yield and its quality.

The temperature below 10 °C leads to impedance of inflorescence and malformations of bunches. Chilling symptoms on leaves are not seen immediately but it may take 2 to 4 days to appear (Datta, 2013) [14]. In banana, Flooding for more than 48 hrs severely reduces growth and after 72-96 hrs, no recovery of mature shoots. Water logging in robusta plant reduces the bunch weight. Higher temperature 31-32 °C, increases the rate of plant maturity & shorten the growth stages. High air temperatures 38 °C and bright sunshine causes choked plant, sunburn damage to fruit. Dwarf Cavendish, temperature below 10 °C leads to impedance of inflorescence and malformations of bunches. Choked bunches are prone to sunburn (Singh, 2012) [45].

High temperature stress is defined as the rise in temperature beyond a critical threshold for a period of time sufficient to cause irreversible damage to plant growth and development (wahid 2007) [52-53]. The growth and development of plants involves a countless number of biochemical reactions, all of which are sensitive to some degree to temperature (Zrobek-sokolnik 2012) [55]. Consequently, plant response to HT vary with the extent of the temperature increase, its duration, and the plant type worldwide, extensive agriculture losses are attributed to heat, often in combination with drought or stress (Mittler 2006) [29].

In apple, the trees, which were exposed to daily alternating temperatures, had lower levels of bud break (vegetative), when the high temperature in the diurnal cycle was greater than 14 °C. Practically no bud break was apparent on trees that that were exposed to diurnal cycles with a high temperature of 20 °C for 8 hours (Naor *et al*., 2003) [31]. Likewise mango, higher temperatures in citrus also enhances vegetative growth but after certain limit, it retards the shoot elongation. Higher temperature (38/28 °C; day/ night temperature) for 10 weeks in Sour orange, Troyer citrange and Valencia oranges showed that seedlings were with short internodes and leaves were markedly shorter as compared to normal ambient temperature (28/22 °C). Beside the effects of high temperature on whole fruit trees, studies have also been carried out on the effect of temperature on individual plant parts in citrus. Direct heat injury results in electrolyte leakage. Based on electrolyte leakage, it was found that lethal temperatures for leaves for a 20 minute exposure ranged from 54.3 for Glen citrange and 56.1 for *Swingle citrumelo* (Ahrens and Ingram, 1988) [3]. The rate of flowering in raspberry cv. Autumn Bliss was dependent upon temperature. The flowering in primocane raspberry cultivars is initiated by the cessation of vegetative growth. Growth of plants at 24.5 °C slowed earliest after just less than 100 days but at temperature below or above this, the cessation of growth was delayed (Carew *et al*., 2003) [10]. In citrus (*Citrus unshiu*), the flower number at an air temperature of 15 °C was greater than at 30 °C. The higher temperature have no effect on double pistil formation, if exposure period is either before or after bud differentiation but the period of stamen and pistil primordia development are more prone to this abnormality (Beppu *et al*., 2001) [9]. Similarly in apricot, the warm temperature (15.9 °C) 3-5 °C higher than the normal results in underdeveloped pistils (Rodrigo and Herrero, 2002) [36]. Fruit set and yield in fruit crops are directly related with the environmental temperature. Likewise in apple and pear low temperatures appeared to promote fruit set on potted trees to different temperature regimes from February to harvest (Tromp and Borsboom, 1994) [47]. Similarly, higher pre-blossom temperature in sweet cherry (Beppu *et al*., 1997) [7] and apricot (15.7 °C). In apricot, at higher temperature, the pistil size is reduced which leads to abnormal flower and ultimately reduced fruit set. In apple cultivars (Cox and Queen Cox) covered under polytunnel, which raised the temperature of fruit trees higher than the outside trees, the fruit number was reduced by 41 and 35% per tree for the two cultivars, respectively (Atkinson *et al*., 1998) [2].

Effect of climate changes due to low temperature impact on fruit crop

Climate change causes less events on extreme low temperatures in tropical and subtropical areas and, but in these areas, not enough chilling hours originate a shortage of low temperatures to break bud dormancy in deciduous fruits (Petri and Leite, 2003) [33], such as apple, pear, peach, and plum. These species will demand higher concentrations of dormancy breaking products and varieties with lower requirements of chilling hours (Fischer, 1999) [16]. In addition, cool nights are necessary to reduce the maintenance respiration of fruits, which lowers their energy costs and increases the positive carbon balance and, hence, the accumulation of dry matter (Gariglio *et al*., 2007) [23]. Also, cool nights favor the coloring of fruits, with an increased production of anthocyanins (Sherman and Beckman, 2003) [42]. In wine grapes, cool nights advance berry coloration and, nowadays, indicate an important criterion for classifying grape-growing regions globally (Tonietto and Carbonneau, 2004) [48].

In relation to the "El Niño" phenomenon, the fruit grower must not only avoid areas exposed to frost, but also has to take into account that crops such as pineapple, banana, starfruit, mango and papaya need climates with minimum temperatures of the coldest month of the year higher than 8 °C (Paull and Duarte, 2011) [35], also in the peach, night temperatures above 10 °C force flowering (Sherman and Beckman, 2003) [42]. The phonological stages including bud swell, bud break, full bloom, flower induction and differentiation, fruit development, maturation yield and quality are affected by climate changes, specifically temperature. In temperate fruit crops, flower induction is highly responsive to temperature and requires low temperature (less than 7 °C for the fulfillment of adequate chilling hours. Flower induction deeply influenced by low temperature, however, strong interaction between genotype, photoperiod and temperature interactively control flowering (Rai *et al*., 2015) [38]. Though, climate warming during winters leads to rapid fulfillment of heat requirement causing variation in both flowering time and flowering duration.

The incidence of spring frost and low temperature at the peak time of fruit setting adversely affects production of fruits. Along with low temperature and untimely rainfall occurrence inhibits pollen transfer due to washing-off of pollen. It has been observed that the flowers are killed below -2.2 °C and bee activity is completely retarded below 4.4 °C (Awasthi *et al*., 2001) [4]. Also, flower induction in temperate fruits is deeply influenced by temperature especially by low temperature, however, strong interaction between genotype, photoperiod and temperature interactively control flowering (Haokip *et al*., 2020) [24]. Therefore, varying climatic conditions at the time of flowering and fruit setting will affects pollination and eventually the fruit production. The optimum temperature for pollination and fertilization in temperate fruits like apple, pear, plum, cherry etc is between 20-25 °C. Low temperatures and rainy or foggy conditions observed to have a negative effect during pollination in cherry in USA (Zavalloni *et al*., 2008) [54]. Low temperature and frost have a negative effect on the metabolism with a corresponding reduction in crop quality and quantity. Chilling resistance and freezing resistance are complex phenomenon, as most plants are capable of hardening to cold i.e. acquisition of increased resistance upon exposure to low temperature. These results in irreversible and proper honor loss of cell proteins and disturbed plasma membrane integrity Tropical plants are more susceptible to chilling than those growing in cold regions (Kumar *et al*., 2018) [27].

Low temperature stress also manifests increased oxidative damage in plants. There is enhancement of antioxidant defense mechanism of the plant under low temperature stress. A major response of the plant under low temperature stress inviters enhanced activities and content of each of the as scavenging enzyme and ran enzymatic antioxidant124, 140. As chilling and freezing temperature cause water deficit inside the cells the compatible solute manital, which alleviates water stress has been shown to protect chloroplastic, phosphokinase from hydroxyl redical of damage under stressfully condition (Kumar *et al*.,2018) [27].

Low temperature leads to production of reactive oxygen species become the light harvesting reaction continue to function (Bohnert *et al*., 1995) [6]. Low temperature stress responses include oxidative stress responses which are also observed under water deficit conditions in higher plants (Bray 1993) [5]. Increased SOD activity in response to stresses has been shown to confer increased protection form oxidative damage (Allen *et al*., 1997) [1]. It is attributed to inhibitions of enzyme sub units under low temperature.

Effect of climate changes due to water stress on fruit crop

Pritchard and Amthor (2005) [34] reported an increase of 1 to 8% for the annual global precipitation, taking into account differences in their geographical distribution. In the past century, precipitation increased between 5 and 10%, preferably in areas of middle and high latitudes of the northern hemisphere, meanwhile, fell by 3% on average in the subtropical zone (Neenu *et al*, 2013) [32]. Water not only plays a key role in plant physiological ecology but also in the enrichment of the planet atmosphere with oxygen. In the process of photosynthesis, two H_2O molecules are broken to produce O_2, released into the atmosphere, while the resulting hydrogen is used in the reduction of CO_2 to carbohydrates (Taiz and Zeiger, 2010) [49]. In fruit trees, many juicy fruits contain between 80 and 90% water, while young twigs and leaves about 50-60% (Friedrich and Fischer, 1999) [16].

Fruit are very demanding in water throughout plant reproductive stages starting from the flower formation until the filling of the fruit, considering that species with indeterminate growth, such as the Passifloraceae, Solanaceae and Caricaceae families, require a constant supply of water (Fischer *et al*., 2012) [18]. In these species, water shortage stops growth and development, while heavy rains during flowering, fruit set or maturation are harmful for flowers and recently set fruits (Fischer and Orduz-Rodriguez, 2012) [19].

Species with determinate growth (flowering, fruiting and harvesting occur in defined periods, as in citrus, mango, etc.) require about 1,000 to 2,000 mm annual rainfall, well distributed, especially from the start of the reproductive phase (Fischer and Orduz-Rodriguez, 2012) [19]. However, there is evidence that rainfall patterns, modified by climate change affect the phenology and reproductive behavior of many fruits, especially in the tropics (Ramírez and Kallarackal, 2015) [37].

A prolonged rainy season or heavy rain after a long dry period can cause cracking of fleshy fruits, thus, water and nutrition have become of great interest to fruit growers (Fischer and Melgarejo, 2014) [21]. Fischer (2005) reported that an imbalance between the volume of water entering the fruit and extensibility of the epidermis and juicy fruits in the ripeness state are more susceptible to cracking by senescence of their epidermal layers.

Furthermore, high humidity environments inhibit transpiration which raises the pressure inside the fruit and therefore may cause cracking (Fischer and Melgarejo, 2014) [21]. Because of these reasons, the nutritional elements that influence the stability and extensibility of the skin play an important role in controlling this disorder (Fischer, 2005) [20]. Therefore, the soil in orchards must be kept at a constant moisture level, slightly below field capacity, with optimum contents of calcium, boron, potassium and magnesium, maintaining nitrogen fertilization at the low average levels (Gordillo *et al*., 2004; Fischer, 2005) [22, 20].

Plant stress occurs whenever more water is lost through transpiration than absorbed from the soil (Kramer, 1989) [26]. Water is an important component of the cell's turgor pressure and essential media for biochemical processes; furthermore, a water deficit translates into dehydration, which severely affects the plant's metabolism and survival (Dwivedi and Dwivedi, 2012) [15]. Water stress is known to damage chloroplasts, thus, affecting photosynthesis (Kramer, 1989) [26].

Fruit trees have different mechanisms to overcome water stress. For example, leaves can extract water from fruits by mid-day stomatal closure (Westwood, 1993) [51]. Also, CAM (crassulacean acid metabolism) fruit plants such as cacti *(Opuntia* sp.) extract water from their fleshy cladoses through the phloem, under extreme water stress conditions (Fischer and Orduz-Rodríguez, 2012) [19]. Furthermore, prolonged water stress conditions during flowering and fruit filling in avocado are conducive to flower and fruit drop, which is a consequence of superficial growing roots (Paull and Duarte, 2011) [35]. In lulo *(Solanumquitoense)*, fruit drop occurs if drought periods extend more than 3 weeks (Fischer and Orduz-Rodríguez, 2012) [19].

Water stress affects the number of fruits produced and their quality characteristics. Thus, fruits are smaller if water stress occurs during the cellular expansion phase (Gariglio *et al*., 2007) [23]. Fischer and Orduz-Rodriguez (2012) [19] recommended, in fruit trees, in general, removing all plant parts that are unimportant for increasing productivity and fruit quality in prolonged "El Niño" scenarios. Plant parts to be removed include: basal and mature senescent leaves, unproductive branches, low quality fruits. Also, for the tree an adequate nutrient supply has to be guaranteed, such as potassium which reduces water consumption and phosphorous stimulating deep soil root growth.

Regulated deficit irrigation has been applied at selected phenological stages of fruit trees to control vegetative growth without yield reduction (Stöckle *et al*., 2011) [44]. (Molina-Ochoa *et al*., 2015) [30] found no yield or quality reduction in pear fruits in Sesquile (Cundinamarca, Colombia), when trees were irrigated with only 55% of the amount of water of the control plants.

Conclusion

Horticulture in India and other emerging nations is at present going through quick change because of progress requests, market and horticulture advances. Pace of these progressions is probably going to increment in not so distant future and may maybe be more significant under environmental change situations. In this way, need to coordinated evaluations of environmental change agri-horti based creation systems for variation and for future moderation. It is now imperative for all of us to have some knowledge about the climate change and its causes and consequences. In conclusion this review effort has been made to define drought, drought resistance/tolerance and their mechanism occurring under water deficit conditions. It would be appreciated that several plant mechanisms be found to be present in plants culminates in crop yield under water stress circumstances.

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