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Heat Stress Effects in Fruit Crops: A Review

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ABSTRACT

Heat stress is one of the most ominous abiotic factors which limit the productivity and quality thereby resulting in to huge economic losses. High temperature affects the morphological, anatomical and physiological and biochemical changes in plant system. The success in overcoming heat stress is limited owing to poor knowledge of heat stress during critical stages of fruit crops. There is urgent need to improve heat stress tolerance by using traditional breeding and transgenic approach. In this paper, we have discuss the effect of heat stress and possible management techniques *viz*., selection of fruit crops, cultivars, rootstocks, canopy management, irrigation, nutrient management, mulching, growth regulator and use of bagging and film spray etc. which can be used to alleviate heat stress in fruit crops.

Key words: Anti-transpiration, Fruit crops, Heat, Root stock, Tolerance.

Adverse environmental condition and temperature extremes are important abiotic stresses causing severe yield loss in fruit crops. Environmental stresses are the primary cause of crop losses worldwide, reducing average yield for the major crops by more than 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). The heat stress caused by short term and constantly elevated temperature results in significant reduction in yield and harvest quality under many regions of the world. The high temperatures encountered at various stages of crop growth and development affect various physiological processes. In general, heat stress considered as any 10-15 °C rise above normal in ambient air temperature for a period of long enough to induce irreparable damage to any aspects of plant growth and development (Wahid *et al.,* 2007). 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). Reproductive processes are also highly affected by heat stress in most plants (Wahid *et al*. 2007).

High temperature causes an array of morphological, anatomically and physiological and biochemical changes in the plants which affect growth and development and may lead to the drastic reduction of economic yield. Heat stress may cause either direct or indirect injury to plants.

1. Direct injury: Includes aggregation and denaturation proteins and fluidity of membrane lipids.

2. Indirect injury: Includes on enzymes inactivation in chloroplast and mitochondria, Inhibition of protein synthesis and degradation and loss of membrane integrity. These alteration results in cell injury or even death which ultimately leads to catastrophic collapse of cellular organization.

MORPHOLOGICAL EFFECT OF HEAT STRESS

Heat stress causes damages like leaves and twig burning, scorching, sunburns in leaves, branches and stems, leaf senescence and abscission, shoot and root growth inhibition, bark cracking, delay flowering/fruiting, poor fruit setting due to sterility, fruit drop and fruit discoloration and quality (Almeida and Valle 2007; Wahid *et al*. 2007).

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Physiological effects of heat stress

Physiological perturbations in plants causes by high temperature. Primary effects on heat injury on enzymes inactivation, inhibition of protein synthesis and degradation, loss of membrane integrity, increased fluidity of membrane lipids, direct injuries includes protein degradation. The secondary effects of heat injury are osmotic stress, oxidative stress, protein denaturation and aggregation, increased fluidity of membrane lipids**,** inhibition of photosynthesis and respiration.

THE EFFECT OF HIGH TEMPERATURE ON GROWTH STAGES OF FRUIT CROPS HAS BEEN GIVEN BELOW

Apple

High temperature in apple shows negative chilling effect. The taste and textural attributes of apples changed in response to climate change during the last 30–40 years. The decrease in acid concentration, fruit firmness and water core development were observed due to higher temperature, regardless of the maturity index. All the changes have resulted from earlier blooming and higher temperatures

during the maturation period (Sugiura *et al.,* 2013). Warm-night fruit had less red skin color than cool-night fruit. The Cox and Queen Cox cultivars of apple covered under polythene which raised the temperature of fruit trees higher than the outside trees and reduced the fruit number in range 41 and 35% respectively (Atkinson *et al.,* 1998). Li *et al.,* (2004) reported that warm weather (mean monthly temperature of 25°C) was associated with slower anthocyanin biosynthesis in Starkrimson Delicious apples. The temperature above 30°C during summer causes water core disorder (Yamada *et al*., 2004). The resistant cultivar 'Fuji' showed a difference in sugar compartmentation and higher fructose and glucose in the vacuoles as against the susceptible 'Orin' apples had higher sorbitol level in cytoplasm and tonoplast (Yamada *et al*., 2005). High temperature causes splitting of fruit in cv. Fuji and bitter pit in Jonagold cultivar.

Apricot

The high temperature reduced in pistil size which leads to abnormal flower and ultimately reduced fruit set (Rodrigo and Herrero, 2002).

Avocado

Heat stress from excessive temperature can damage crop. Extreme heat can shut down the photosynthetic activity thereby affectively productively and also sunburn damage in fruit (Anonymous, 2017).

Banana

The high temperatures affect banana growth and production. The leaf production and relative leaf area growth was affected beyond 33.5°C (Turner and Lahav, 1983). Higher temperature (31-32°C) shortening the bunch development period by increases the rate of plant maturity in Banana (Turner *et al*., 2007). Banana plant can relatively persist under prolonged water stress, but the combined effects of deficit soil moisture along with prolonged prevalence of temperatures beyond 35°C can reduce banana production (Thornton and Cramer, 2012). The Cavendish banana fruit exposed at high temperature greater than 24°C got fruit remained green owing to retention of chlorophyll and associated thylakoid lamellae (Blackbourn *et al.,* 1989). The physiological disorder of sunburn and choking of bunching are associated with high air temperature (>38°C) in banana (Stover and Simmonds, 1987).

Cape Gooseberry

Flowering was inhabited in cape gooseberry when air temperature goes beyond >30°C (Fischer and Orduz-Rodriguez, 2012).

Custard Apple

The air temperature more than 40°C can lead to no fruit setting in custard apple (Rao, 2016).

Cherimoya

The warm temperature determine the production of low viability pollen and therefore asymmetrical and small fruits containing few seeds (Higuchi *et al.,* 1998).

Citrus

The temperature (35/28°C) for two weeks affecting seedling growth with short nodes and small leaves in sour Orange, troyer citrange and valencia oranges (Ahrens and Ingram. 1988). Levitt (1980) reported that the sour orange plants were killed when plants exposed to 50.5°C for 15-30 minutes. The number of flower in fruit was more at 30°C temperature (Carew *et al*., 2003). The reduction in fruit size, sugar and acid content when air temperature was 35°C reported by (Hutton and Landsberg, 2000). Sunburn in fruits can be attributed to heat/light stress.

Grapes

High temperature after foundation pruning delays buds sprouting in Thompson Seedless cultivars on Dogridge rootstock (Sharma *et al.,* 2013). The temperature more than 35°C hindered fruit set in grapes (Fischer and Orduz-Rodriguez, 2012).The reduced fruit set can attributed by reduced ovule or pollen viability and pollen tube growth. The high temperatures advance harvest times in grapes and also changed fruit quality. Higher sugar concentrations, low acidity and alterations in aroma compounds has been recorded in fruit due to high heat. The extreme hot temperatures may affect wine aroma and color (Mira de Orduna, 2010). The soluble solids content increased with the increase in temperature from15 to 30°C in the grapes (Coombe *et al*., 1987). High day temperature and exposure to sunlight during berry development result into berry discoloration thereby affecting the market acceptability. High diurnal variation has found to increase the incidence of pink berry disease in Thompson Seedless and its mutant (Sharma *et al.,* 2013).

Guava

H Poor fruit set occurs in north India during summer month where climate is characterised by high temperature and low humidity (Chadha and Pandey, 1986).

Japanese Pear

High temperature during early fruit development of water core disorder (Sakuma *et al.,* 1995).

Kiwi fruit

The effect of high temperature at pre-harvest stage and quality of fruits when grown under 3-4°C more than ambient air temperature during mid March to mid May had lower soluble solids, more firmness and had higher starch concentration in both core and cortex tissue (Hopkirk *et al*., 1989).

Litchi

High temperature reduced the both the duration of flushing and interval between flushing. High temperature can cause significant damage to shoot and root growth, sunburn of leaves and maturity of fruits, high temperature also cause leaf absicission and drying of branches and stems, fruit drop,

fruit cracking and sunburn in litchi (Menzel and Waite, 2005). Heat injury to the fruits are common where daily air temperature goes (>40°C) (Singh *et al.,* 2012). The heat injury in litchi fruits and mostly occurs on the exposed fruit on south side of the tree. The fruit injured in litchi fruit showed dark blotches on the skin without any damaged to the pulp.

Mango

Higher temperatures lead to stronger vegetative bias under sufficient nutrient and water availability (Laxman *et al*. 2016). The panicles emerging late experiencing higher temperatures had higher percentage of hermaphrodite flowers (Ramaswamy and Vijaya Kumar 1992), signifying that the proportion of male and hermaphrodite flowers change with the prevailing temperatures. Thus, the sudden changes in temperatures due to climate variability would influence not only the vegetative and reproductive cycles but also proportion of female flowers in the panicle, leading to effects on productivity. The pollen viability and fruit set was reduced when mango plant exposed to temperature ≥ 35°C.

Macadamia

The plant growing under constant day temperature 35°C in controlled environment produce multiple, spindy branches and chlorotic leaves (Armstrong, 1980).

Papaya

The female sterility (non-functional female part) and become functionally male when temperature rises more than 35°C. The severity of sterility increases with the directly temperature occurs in bisexual cultivars. The air tendency varies with the cultivars and within cultivars (Paull and Duarte, 2011).

Peach

The shortening of earlier phases of fruit development at high temperature can decrease fruit size and yield (Stockle *et al*., 2009).

Pineapple

Higher temperature (28/18°C max/min.) can lead to development of translucency disorder in fruit (Paull and Reyes, 1996).

Prickly pear

The plant died when exposed to temperature more than 65°C in Prickly pear (Levitt, 1980).

Miscellaneos Tropical Fruits

The species like pineapple, coconut palm, cherimoya, soursop, sugar apple were heat-tolerant, whereas Java apple, rose apple and longan were sensitive to heat stress (Yamada *et al.,* 1996).

Raspberry

The rate of flowering in raspberry cv. Autumn Bliss was dependent on temperature. The sensation growth of plant delayed above 24.50°C thereby affecting flowering in primocane raspberry cvs. (Carew *et al*., 2000).

Strawberry

Warm weather develops serious disorder (Albinism) in strawberry. Fruits suffering from the malady appear blotted and develop pink or white area on their surface, the pulp remains pale (Sharma *et al*., 2003).

Sweet Cherry

Abnormal pistil development was recorded when plants expose to high temperature (≥ 35°C) at flower developing stage (Beppu *et al*., 2001).

High Temperature Tolerance Mechanism

The fruit plants have inherent ability to survive high temperature and the ability to acquired thermo tolerance. The thermo-tolerance is facilitated by morphological or anatomical adaptation and synthesis of distinctive classes of protein like HSPs.

Morphological Adaptation

Heat and drought tolerance mechanism like deep root system (aonla, ber), leaf shedding (aonla, ber), reduce leaf area (aonla, tamarind, ker), leaf epicular waxes, leaf latex, leaf orientation (vertical orientation, rolling their leaves along the axis), water binding mechanism (cactus pear, fig) and presence of thorn (ker, ber), there by maximize conductive or convective loss of heat.

Anatomical Adaptation

The fruit crops have adaption such as leaf surface having sunken stomata (ber, ker, cactus pear), thick cuticle (fig, cactus pear), wax coating (ker, lasora and fig) and pubescence (ber, phalsa and tamarind) and tolerate heat stress (Pareek and Sharma, 1991).

Thermo-Tolerance

Thermo-tolerance can be improved by the accumulation of various compounds of low molecular mass known as thermo-protectants as well as phyto-hormones. Exogenous application of these molecules has benefited plants growing under heat stress. Alternatively, transgenic plants over-expressing the enzymes catalyzing the synthesis of these molecules may be raised to increase their endogenous levels to improve heat tolerance. In response to stresses, plants also accumulate various thermo-protectants such as proline (Pro), glycine betaine (GB) and trehalose (Tre). Heat tolerance is induced by many other phyto-hormones such as salicylic acid (SA), abscisic acid (ABA), polyamines (PA), brassinosteroids (BRs) and ethylene (Eth) and putative signaling components such as nitric oxide (NO). The level of ABA rises under heat stress, which helps in thermo-tolerance through up- or down-regulation of various genes.

The rise in ABA further increases the production of heat shock proteins (HSPs). The majority of stresses induce the production of group of protein called heat shock protein (HSPs). There proteins are grouped into different molecular weight: HSP 100, HSP 90, HSP 70, HSP60 small heat shock

Table 1: Heat and drought tolerant rootstock in fruit crops.

Fruit crop	Rootstock	Reference
Almonds	*Prunus amygdaliformisPrunus elaeagnifolia, Prunus xerophila*	Nimbolkar *et al.*, 2016
Apple	MM. 101	Nimbolkar *et al.*, 2016
Ber	Jhar ber (*Ziziphus nummularia*), (*Ziziphus lotus*)	Nimbolkar *et al.*, 2016
Citrus	Rough Lemon(*Citrus jambhiri*), Rangpur Lime (*Citrus limonia),*Carrizo citrange	Nimbolkar *et al.,* 2016 Molinara *et al.,* 2004
Grapes	110 R, Dogridge	Nimbolkar *et al.*, 2016
Mango	13-1	Nimbolkar *et al.*, 2016
Peach	Almond, Peach x almond, *Prunus persica x Prunus davidiana*	Nimbolkar *et al.*, 2016

protein (SHSPs) and ubiquitins. HSP act as molecular chaperons, regulate protein folding, accumulation and transportation and removal of damaged protein. The expression of HSPs positively correlates with the acquisition of thermo-tolerance and the over-expression of HSPs often results in enhanced thermo tolerance and ultimately improves physiological parameters such as photosynthesis, assimilate partitioning, along with water and nutrient efficiency of the plants The hs-response is characterized by (i) a transient alteration of gene expression (synthesis of heat shock proteins: HSP) and (ii) by the acquisition of a higher level of stress tolerance (acclimation). Binding of HSP with particular polypeptide within subcellular compartment avoid denaturation of many proteins at high temperatures.

MANAGEMENT PRACTICES TO ALLEVIATE HEAT STRESS

1. Selection of Fruit Crops

Perennial fruits species should be chosen that are adapted to the high temperatures likely to occur in the specific location. Heat and drought tolerance mechanism like deep root system, leaf shedding, water binding mechanism, presence of thorn, leaf orientation, vertical and rolling of leaves and well formed canopy. The fruit crops like ber, pomegranate, aonla, fig, ker, tamarind, bordi (*Ziziphus* species), karonda, lasora, khejri and Indian fig can be selected for growing in heat prone area.

2. Selection of Cultivars

The cultivars for drought and heat tolerance in fruit crop *viz*. Ruby (Pomegranate), Arka Sahan (*Annona)*, Deanna and Banana-cultivars belonging to BB genome shown to be drought tolerant *viz*. Karpuravali and Kanthali (Bose and Mitra,1996). In temperate fruit crops, the heat tolerance cultivar are Elsanta, KHope and Camarosa in strawberry (Kesici *et al.,* 2013) and BR1 Chimarita, Tropic Beauty and Atens in Peach (Carpenedo *et al.,* 2017).

3. Rootstock

One of the strategies to improve fruit tree response to heat stress and water deficit conditions is the use of tolerant rootstock genotypes. The use of heat and drought tolerant rootstocks would minimize the immediate effects of dry conditions and enable the variety to recover quickly. With increased awareness about the use of rootstocks in overcoming the adverse effects of heat and drought started using rootstock for the cultivation (Table 1).

Canopy Management

Extent of fruit shading by leaves can be manipulated by the choice of cultivars, irrigation methods and fertilizer management methods and pruning and training procedures. Any treatment that reduces canopy cover will increase sunburn, such as foliar diseases, wilting due to inadequate irrigation and excessive or late pruning, excusive summer pruning and leaf stripping. Controls of sunburn in fruits starts with developing good leaf cover in the canopy to shade the fruit. Fruits most susceptible to sunburn will be those that are most exposed sun then fruit which are not shaded in the afternoon.

Irrigation

Irrigation should be given just before or during heat waves to avoid heat stress and sunburn (Lal and Sahu, 2017). The major method to reduce heat stress is by meeting evapotranspiration demand with irrigation. Use of overhead watering, sprinkling and misting can also reduce of tissue temperature and lessen water vapor pressure deficit.

Nutrient Management

Proper plant nutrition is one of the good strategy to alleviate the heat stress (Waraich *et al*., 2012). The Split application of N and K fertilizers improve plant growth under moderate heat stress. Foliar spray of 2% DAP + 1% KCl (MOP) also used to alleviate heat stress. During the spray, sufficient moisture should be present in the soil for avoiding leaf scorching. Foliar spray of 0.5% zinc sulphate + 0.3 % boric acid + 0.5 % + Ferrous sulphate + 1% urea.

Mulching

Mulches also help in checking the transpiration thereby keeps canopy cool. Use of reflective, low density, organic and mulches such as straw will reduce the surface radiation by reflection and dissipation of radiative heat and conserve moisture by using reflective mulches. Shading cloth is used for partial shading by reducing advected heat and total incoming radiation.

Anti-Transpiration

Anti-transpiration chemical used to minimize the evapo-

-transpiration rate Application of foliar spray of 3% Kaoline can reduce heat stress by reduce evapotranspiration.

Growth Regulators

The stress tolerance is can be induced in plant by exogenous spray of PGR**.** The salicylic acid treatment can maintain higher photosynthesis in grape leaves under heat stress (Wang, 2010). Spray of 100 ppm salicylic acid for increase stem reserve utilization and increasing Harvest Index of crops under stress (Wang *et al*., 2007).

Fruit Bagging

Large percentages of exposed fruits at risk of sunburn can be protected by using shade cloth (10-30% shade).

Fruit Suppressants/ Film Spray

Use of film spray can reduce or eliminate sunburn. These materials are Kaolin clay based and leave a white particle film on the fruit such as Surround, Screen Duo and Purshade. There are also film products that protect fruits from sunburn but do not leave a white residue, such as Raynox (Lal and Sahu, 2017).

Bark Painting

High temperature damage to trunk cambium can be cracked by spraying or painting the bark of exposed trunks and branches with reflective white coating.

CONCLUSION

High temperature stress is the second most important stress after drought that adversely affects on growth, productivity and quality of fruit plants. Hence, concern over the high temperature has increased due to the expected increase in frequency and amplitude of this stress in near future. There is urgent need to screen the wild relatives of crops and also other related species as rootstocks for heat tolerance may be intensified. Efforts should also be intensified to develop heat tolerant varieties by using conventional breeding and biotechnological approaches. To mitigate the adverse impact of heat stress on management practices have been found to be only strategy which can be effectively used to alleviate heat stress in fruit crops.

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