Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Botany

Elixir Appl. Botany 39 (2011) 4745-4747

ISSN: 2229-712X

Effects of high temperature on fruit crops

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ARTICLE INFO

Article history:
Received: 7 August 2011;
Received in revised form: 21 September 2011;
Accepted: 27 September 2011;

Keywords
Temperature,
Fruit,
Enzymes,
Life cycle,
Reproductive.

ABSTRACT

Temperature influences the life cycle of fruit plant in a variety of manners. Adverse effect of high temperature has been noted during both vegetative and reproductive growth stages in various fruit crops. The best responses for every plant either for vegetative growth or for its reproductive potentials are obtained in the cardinal temperature ranges, which includes minimum, maximum and optimum. 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.

Introduction

The effect of high temperature on different growth stages (phenology) of fruit crops is summarized under following under sub-heads:

- Vegetative growth
- Flowering
- Fruit yield
- Fruit quality
- Disorders
- Metabolic processes

Vegetative growth

Under high temperature exposure (43°C) in almond bud failure like symptoms appear in which there is complete separation of distorted and compressed cells from surrounding tissues takes place by a periderm like layer. However, resistance to this trait is governed by increased levels of endogenous ABA. In plants showing bud, failure like symptoms ABA level remains stable with increasing temperature but in the genotypes showing resistance to this trait, the ABA concentration rises with the temperature. Higher temperature in temperate fruits can negate the chilling effect. 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). In raspberry, the optimum temperature for node production is 22 °C and it continues to support growth up to the range of 25 °C. Above this range, it becomes supraoptimal and node production is reduced (Carew et al., 2000).

Mango cultivars exposed to different day/night temperatures (15/10, 20/15, 25/20 and 30/25°C) for 20 weeks showed that vegetative growth increased with increasing temperatures. All cultivars grew vegetatively at 25/20 and 30/25 °C. 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).

Flowering

The various stages starting from flower bud differentiation, anthesis, rate of flowering and even development of various parts of flowers is influenced by the prevailing environmental temperature. Lack of chilling associated with mild winter conditions results in abnormal pattern of bud break and development in temperate fruit trees. After strict deprivation of cold temperature in peach all floral primordia died within 5 months. In Redhaven peaches grown at 20/15 °C from October to December, it was found that the bud necrosis could be attributed either to the weak establishment of vascular connections between stem and floral buds or the unavailability of the sugars. However, the sugars *viz.*, sorbitol and sucrose concentrations remained high in cushion and bud scales but low in floral meristem. Thus, it seems that under high temperature the bud scales and cushion beneath the meristem primordia served as strong sink as compared to meristem. The temperature rise at the tune of even 6-7 °K at the end of January in apricot (during the period of rapid floral development) appears to increase the flower bud abscission. In most fruit crops, generally higher temperature decreased the days interval required for flowering and cooler temperature though required more days for flowering but the number of flowers produced

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increased proportionally at this temperature. 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). In citrus (*Citrus unshiu*), the flower number at an air temperature of 15 °C was greater than at 30°C.

In sweet cherry, there is abnormality in pistil development, if the flower bud development period (mid July) exposed to higher temperature (≥ 35°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). Similarly in apricot, the warm temperature (15.9 °C) 3-5 °C higher than the normal results in underdeveloped pistils (Rodrigo and Herrero, 2002). While evaluating the effect of temperature on flowering of peaches, it was found that the period of full bloom with treatments of 25/15 and 30/15 °C were 5 and 8 days earlier, respectively than for the 20/15°C treatment. With the increase in temperature, rate of pollen development and tendency for the stamens to abort increased (Shen et al., 1999).Temperature not only influences the development of various parts of flowers but also determines the type of inflorescence. In litchi cultivars, when trees exposed to day/night temperatures of 30/25 °C and 25/20 °C did not flower and temperatures of 20/15 and 15/10 °C gave rise to variable proportions of vegetative, leafy panicles and leafless panicles depending on the cultivars (Table 1).

Similarly, in citrus, more leafless floral shoots are produced at cooler temperature (20/ 15 °C day/night) and higher soil and air temperature enhanced production of leafy floral shoots.

Fruit set and Yield

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). Similarly, higher pre-blossom temperature in sweet cherry (Beppu et al., 1997) 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). In Cherimoya (tropical fruit), the effect of warm (30/25 °C) and cool (20/15 °C) day/night temperatures on fruit set and fruit growth investigation revealed that the low fruit set at warm temperature regime was ascribed to both pollen and stigma damage from heat stress, although the former was more sensitive to this stress (Higuchi et al., 1998).Beside pre-blossom and blossom temperature, the higher temperature during fruit let stage also affect the fruit retention. Three year old Satsuma mandarin cv. Oktuge Suwase budded on trifoliate orange rootstocks, when exposed to 30-35 °C for 48h in a controlled environment increased the fruit drop. It was found that following exposure, IAA concentration increased in the leaves but decreased in the fruitlets. Conversely, there was little effect on ABA in leaves but ABA concentration in ethylene produced at higher temperature responsible for fruit drop, as with the increase in ethylene level there was simultaneous decrease in polyamines level, which play an important role in fruit retention.

Fruit quality

Quality is a measure of degree of excellence or degree of acceptability by the consumer. It includes external parameters (color size, shape and defects) and internal parameters (texture, flavour and nutritional qualities).

External parameters

Fruit size under polytunnel in Cox and Queen Cox apple was enlarged as compared to cooler temperatures. The increased fruit size under high temperature treatment was attributed to decreased cropping intensity (Atkinson et al., 1998). Natural colour development in fruits is one of the external quality parameter visibly sought after by the consumer. High temperature generally reduces the anthocyanin accumulation in fruit crops. In grapes, veraison is a critical period for the berry tissues to perceive environmental stimulation and trigger anthocyanin biosynthesis. At this stage, night temperature is more critical than the day temperature. Anthocyanin synthesis in the skin of berries grown at high night temperatures (30°C continuous day and night) was reduced as compared to that of berries grown at low night temperatures (30/15 °C ; day/night). The reduced coloration at higher temperature has been correlated with decreased activity of *Phenyl alanine synthase* (PAL) (Boss et al., 1996), *Chalcone synthase* (CHS) and *UDP-glucose, flavonoid 3-o- glucosyltransferase* (UGFT) (Mori et al., 2005). Environmental concerns such as global warming in the leading grape producing countries may further accelerate this problem. Similarly, in Starkrimson Delicious apples grown at cooler environment (mean monthly temperature of 18.6 °C) showed rapid anthocyanin accumulation but warm weather at a different location (mean monthly temperature of 25 °C) was associated with slower anthocyanin biosynthesis (Li et al., 2004). In this case, major interference due to temperature was reduced activity of PAL and less amount of reducing sugars (Li et al., 2004). Fruits of Cavendish banana subgroup failed to degreen, when ripened at the high temperatures of the tropics (>24 °C). The fruits remained green because of the retention of chlorophyll and associated thylakoid lamellae (Blackbourn et al., 1989). In citrus, if mature fruits are left on the trees during summer months, chlorophyll returns to rind and carotenoid content decreases. This condition is referred to as regreening, degree of which is influenced by high temperatures.

Internal parameters

Kiwifruit grown under high temperature (3-4 °C more than the ambient temperature) during mid march to mid may had lower soluble solids, more firmness and had higher starch concentrations in both core and cortex tissue (Hopkirk et al., 1989). However, in the grapes also a vine crop, the soluble solids content increased with the increase in temperature from 15 to 30 °C (Coombe et al., 1987).

Disorders

Early water core of apple cultivars in which there is sorbitol accumulation takes place was increased by high temperature above 30 °C during the summer (Yamada et al., 2004). The resistant cultivar 'Fuji' showed a difference in sugar compartmentation and higher fructose and glucose in the vacuoles. Conversely, the susceptible 'Orin' apples had higher sorbitol level in cytoplasm and tonoplast (Yamada et al., 2005). These results implied that higher fruit temperature may increase tonoplast permeability especially to sorbitol in the early watercore susceptible 'Orin' cultivar but not in resistant 'Fuji'.

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

Albinism of strawberry is a serious disorder, which has attained alarming situation in USA, Belgium and Netherlands. Fruit suffering from this malady appear blotted and develop pink or white areas on their surface, the pulp remains pale. It occurs frequently in the fields during peak fruit production in localities experiencing warm weather. This disorder is also favoured by black polythene as it raises the soil temperature (Sharma et al., 2003).

Metabolic processes

High temperature also has a direct effect on the processes like respiration and photosynthesis. In longan and mango, with the increase in temperature from 15 to 35 °C, the photosynthesis rates increased, when the vapour pressure deficits were maintained within 1.5 kPa. However, the photosynthesis rates decreased, when the temperature was increased further at the same vapour pressure deficit (Fukamachi et al., 1999).

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Table 1 Effect of temperature and cultivars on percentage of terminal branches flowering (column means followed by different letters are significantly different at P=0.05)

Cultivars	15/10 °c			20/15 °c		
	Vegetative	Leafy panicles	Leafless panicle	Vegetative	Leafy panicles	Leafless panicles
Tai So	0	93.0 a	7.0 a	50.0	49.8	0
Kwai May Pink	0	54.5 b	45.6 b	20.0	68.7	8.2 a
Salatheiel	0	0	100.0	16.5	19.5	58.1bc
Wai Chee	0	0	100.0	4.0	13.5	80.5 c