REVIEW ARTICLE

Impacts of climate change on fruit physiology and quality

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Abstract

Global warming which is predicted by general circulation models and supported by mounting evidence will lead to an excessive change in climate conditions and therefore crop production. Global temperature is supposed to increase by 1,4 up to 6,4 °C by the year 2100 while CO_2 concentration is projected to increase in the range from 550 to 850 ppm. Phase of dormancy enables fruit and nut species to withstand winter temperatures in their original habitat. Climate change impacts winter chilling with negative consequences on fruit yield and quality as most temperate fruit and nut species require adequate winter chilling for normal production in forthcoming season. To overcome dormancy requirements, strategies like cultivar selection, dormancy avoidance (defoliation), manipulation of microclimate (irrigation), application of colour sheds and chemicals that trigger dormancy have been examined. Higher temperature provokes faster tree maturation of fruits which results in earlier harvest date. In average, fruit is harvested up to two weeks earlier. From the physiological point of view, most plants function normally at temperature range of 0 to 40 °C but not fruits. Fruits are known to mature normally at temperature as high as 35 °C, whereas higher temperatures block ripening processes. Combined effect of elevated temperature and CO_2 level is a decrease in starch, soluble sugars, proteins and majority of minerals and increase in oil content. The effect of temperature for most ingredients is more pronounced than that of CO_2. From the nutritional point of view fruits and vegetables grown under elevated temperature and CO_2 level contain more phenols and ascorbic acid.

Key words: climate change, temperature, CO_2, photosynthesis, dormancy

Introduction

Over the past million years, climate changed between glacial and interglacial periods as Earth shifted between ice ages. As evident from ice drilling experiements from Vostok and Dome C in Antarctica CO_2 values increased from 180 ppm during the ice age up to 280 ppm during interglacial periods (Blunier and Jenk, 2013; Monnin et al., 2004). CO_2 content of 280 ppm persisted till the industrial revolution, afterwards once again increased and reached 400 ppm recently (DaMatta et al., 2010).

According to projections (Haywood and Schulz 2007) CO_2 concentration will reach 700 ppm by the end of the century and temperature will increase by 1.8 – 4.0 °C (DaMatta et al., 2010). Climate change projections for fruit-producing areas predict an increase of annual temperature of 3 to 6 °C in Brazil, 3 to 5 °C in Spain, 3 to 4 °C in Italy, 3,3 to 4,4 °C in southern California and 4,7 °C in China (Stöckle et al., 2011). Climate change is known to affect chilling (Baldocchi and Wong, 2008; Luedeling et al., 2011).

Physiological bases for plants adaptability to climatic conditions

In order to survive during the winter period, fruit trees from cold winter climates fall dormant. Dormancy is a physiological state where quite accurate factors like temperature below certain threshold and longevity (duration) are necessary. Chilling requirements are crucial for choosing the right tree cultivar for a certain climatic zone in order to have high orchard productivity. Period of dormancy enable fruit trees to tolerate freezing temperatures in their original habitats (Luedeling, 2012). During that period any visible growth is

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suspended and most of physiological processes are stopped or slowed down. Growth resumes when cold season is over (Luedeling, 2012). Plants in general have mechanism to sense temperature during the whole season (Vegis, 1964) and thus modulate their physiology according to environment factors.

Early blooming and harvest date for fruits around the world indicate that dormancy processes are changing (Luedeling, 2012).

Impact of global warming on crop production

The productivity of crops and livestock, including milk yields, may decline because of high temperatures and drought-related stress.

Regions of the world that now depend on rain-fed agriculture may require irrigation, bringing higher costs and conflict over access to water.

Shifting seasonal rainfall patterns and more severe precipitation events and related flooding may delay planting and harvesting.

Optimal growing temperatures may shift to higher latitudes, where soil and nutrients may not be as suitable for producing crops, leaving lower-latitude areas less productive.

Insect and plant pests may survive or even reproduce more often each year if cold winters no longer keep them in check. New pests may also invade each region as temperature and humidity conditions change, e.g. - Lower latitude pests may move to higher latitudes

Strategies to overcome chilling requirements under warmer climatic conditions

Careful selection of cultivars

As reported by Guerriero et al. (2010), during warm winter in 2006/2007 apricot cultivars native to northern Italy showed unusually low fruit set. On the other hand genotypes from warmer climate conditions (Southern Italy, Northern Africa) produced heavy crop also under unusual mild winter conditions.

Dormancy avoidance

As reported by Griesbach (2007), defoliation of fruit trees can induce dormancy without requiring chilling.

Manipulation of microclimate

Shading during dormancy can advance bloom date in apricots (Campoy et al., 2010). Carefully planned irrigation especially overhead irrigation has cooling effect on buds during the warmer period of day.

Colour sheds

Light selective colour sheds have been proved to modify the metabolism of tomato and bell pepper (Ilic et al., 2012; Shahak et al., 2009). Employing colour sheds of different colours (yellow, pearl, red etc.) resulted in higher productivity, better storage life and higher antioxidants content.

Chemically triggered dormancy

Dormancy can be broken by a number of chemicals if applied in appropriate period. Most of these chemicals can be toxic to plants if not applied properly decrease yield. Hydrogen cyanamide was widely used to promote blooming in apples (Ashebir et al., 2010) and pears (Chabchoub et al., 2010). Recently some plant growth regulators like thidiazuron (Campoy et al., 2010) have been effective in promoting blooming.

Application of 1-MCP to counteract the effect of stress ethylene during high temperature or drought stress

1-MCP is known to protect the crops during moderate heat and drought conditions and increase yield (Mohammed et al., 2014).

Food quality and yield as influenced by global warming

Many factors are known to influence fruit development in orchard. Temperature and water usually considered as the most important. Physiological processes in plants range from 0 to 40 °C. However temperature range for the development of fruits and vegetables is somewhat narrower (Moretti et al., 2010). Temperature is known to affect both photosynthesis and respiration and their ratio must be high in order to achieve high yield. At moderate temperatures (15 °C) the ratio is higher than 10 which might explain their better development in temperate regions (Moretti et al., 2010).

Photosynthetic activity is in positive correlation with temperature until certain treshold. Higher temperatures provoke inactivation of enzymes and plant no longer has the ability to cope with heat stress. Under extreme conditions in tropics fruit may reach 40 °C, while temperatures above 35 °C are considered to stop ripening process and temperatures above 35 °C suspend ethylene production in climacteric fruit. In the examination of protein spots expression during hot water treatment of peach fruit (48 °C, 10 minutes) was found that 43% of spots related to stress response, 17% to cell structure, 13% to protein fate, 7% to glycolytic pathway, 3% to ripening and senescence while 17% were unclassified (Zhang et al., 2011). Higher temperatures during growing season result in earlier harvest. Tourre et al., (2011) found evidence that 'Pinot' noir grape matures 14 days in advance when compared to the average vintage time (1706-1970). In lake of Constance area in general , apples are harvested at least two weeks in advance as compared to long time average harvest date (Streif, 2011).

Photosynthesis rate of C3 plants like rice and wheat is at maximum at temperatures from 20 – 32 °C (DaMatta et al., 2010). C3 crops show nonlinear increase in respiration rate from 15 – 40 °C followed by a rapid decline at higher temperatures (Porter and Semenov, 2005).

Regarding food quality, increase in temperature should have more pronounced effect than elevated CO_2 (DaMatta et al., 2010). Results of experiments are different and sometimes controversial. Thomas et al., (2003) reported that higher temperature and CO_2 cause decrease of soluble sugars and starch in soybean, while Fangmeier et al., (1999) found that elevated CO_2 caused small increase in starch content in grains. Litterature data show general decrease of minerals under elevated CO_2 level (DaMatta et al., 2010). Oil yield increase with increasing temperature (Thomas et al., 2003) found the highest oil content at 32 °C, oleic acid increased while linolenic acid decreased. Total protein content decrease under elevated CO_2 level as reviewed by DaMatta et al., (2010). Fruits and vegetables grown under elevated temperatures and CO_2 level contain more bioactive compounds (phenols, ascorbic acid) due to stress conditions.

Conclusions

Global warming is inevitably happening and affect many aspect of life on earth. Tere are may projections how our climate will look like; temperature projections predict an increase from 1,4 up to 6,4 °C by the year 2100 while CO_2 concentration might increase to 850 ppm. That will inevitably change fruit production among others. Symptoms like earlier blooming and harvest time are already seen. Negative consequences like deprivation of required winter chilling and changed content of bioactive compounds are most often reported changes due to global warming. If the trend of temperature rise is to continue, new strategies should be taken to counteract the consequences. Use of suitable cultivars, application of chemicals and sheds are already available tools.

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