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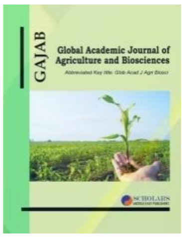

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Review Article

Physiological Studies in Horticultural Crops -An Overview

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Abstract: Plant physiology is the science which is connected to the material and energy exchange, growth and development, as well as movement of plant. The field of crop physiology includes the study of all the internal activities of crop plants, which are studied at many levels in the scale of size and time. Physiological study in horticultural crops like other crops, involves the basic and practically useful studies on processes such as water and nutrients in plant, nutrient supply of plants, production of primary and secondary metabolites, photosynthesis, respiration, transpiration, evapo-transpiration, plant stress physiology, growth and development responsible for crop production with the techniques to quantify and optimization of these processes for final economic yield production. The production of horticultural crops can be characterized as an open and highly complex system affected by climate, soil, cropping system and interactions between these factors. Plant growth and development are directly and indirectly influenced by environmental factors, in order to obtain a successful production it is essential to understand clearly how these factors affect plant physiology. This paper review the studies related with the major environmental factors and their physiological effect on production of horticultural crops.

Keywords: Plant physiology, horticulture, Photoperiod, light intensity, temperature.

INTRODUCTION

Plant physiology is the science which is connected to the material and energy exchange, growth and development, as well as movement of plant. Plant physiology is the science that studies plant function: what is going on in plants that accounts for their being alive (Salisbury and Ross, 1992). Another definition of plant physiology by Taiz and Zeiger (2010) is the study of plant function, encompassing the dynamic processes of growth, metabolism and reproduction in living plants. The field of crop physiology includes the study of all the internal activities of crop plants, which are studied at many levels in the scale of size and time. At the smallest scale are molecular interactions of photosynthesis and internal diffusion of water, minerals, and nutrients. At the largest scale are the processes of plant development, seasonality, dormancy, and reproductive control. Crop physiology is the investigation of the plant processes driving growth, development, and economic production by crop plants. Hence, these processes are the foundation for understanding the concepts of crop production for an agriculturalist (Sewhag *et al.*, 2011**)**. Physiological study in horticultural crops like other crops, involves the basic and practically useful studies on processes such as water and nutrients in plant, nutrient supply of plants, production of

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primary and secondary metabolites, photosynthesis, respiration, transpiration, evapo-transpiration, plant stress physiology ,growth and development responsible for crop production with the techniques to quantify and optimization of these processes for final economic yield production (Sewhag *et a.l,* 2011; ordog *et al*., 2011). All of these processes in plants are affected directly or indirectly by environmental factors. The production of horticultural crops can be characterized as an open and highly complex system affected by climate, soil, cropping system and interactions between these factors (Lentz, 1998). Given that plant growth and development are directly and indirectly influenced by environmental factors (Schaffr and Andersen, 1994), in order to obtain a successful production it is essential to understand clearly how these factors affect plant physiology (Wien, 1997). There are different works conducted in relation to environmental factors and growth and development of horticultural crops. From the different physiological studies, this paper focuses on the studies related with the major environmental factors.

Physiological Studies Related with Water

Water plays a crucial role in the life of plant. It is the most abundant constituents of most organisms. Water typically accounts for more than 70 percent by weight of non-woody plant parts. The water content of plants is in a continual state of flux. The constant flow of water through plants is a matter of considerable significance to their growth and survival. The uptake of water by cells generates a pressure known as turgor (Ordog *et al*., 2011). Photosynthesis requires that plants draw carbon dioxide from the atmosphere, and at the same time exposes them to water loss. To prevent leaf desiccation, water must be absorbed by the roots, and transported through the plant body. Balancing the uptake, transport, and loss of water represents an important challenge for land plants. The thermal properties of water contribute to temperature regulation, helping to ensure that plants do not cool down or heat up too rapidly. Water has excellent solvent properties. Many of the biochemical reactions occur in water and water is itself either a reactant or a product in a large number of those reactions (Bray, 2000). Water is the most limiting resource that plants need to grow and function for the best efficiency or productivity in terms of biomass. Water is important to the physiology of plants due to its crucial role in all physiological processes and due to the large quantities that are required. Plant water relation can be detected by measuring soil moisture status, leaf or stem water potential (ψw), leaf relative water content (RWC), sap flow or trunk and fruit diameter (Gindaba, 2005).

Water loss of crops is driven by solar radiation but modified by temperature, vapor pressure gradient, boundary layer of still air, leaf area and crop structure that influence light interception and stomatal opening. Leaves intercept radiation that drives transpiration. They provide the most active transpiring surfaces. As the leaves intercept radiation, the energy warms the leaves and provides the energy for the evaporation of water within the stomatal cavities of the leaves. Broad canopies and trees or orchards spaced more closely will intercept more light and use more water. Wider or larger tree forms use more water than thinner or more vertical forms. According to the study conducted by Angelocci and Valancogen, (1993), Apple tree water use has a good correlation to leaf area. Studies from different regions (Europe, USA and NZ) indicate that apple tree water use rates on sunny days are approximately 1 – 1.7 L m^{-2} leaf per day but it could exceed 2.5 m^{-2} leaf per day in arid climates. Trees with many shaded leaves will have lower water use efficiency because the interior shaded leaves still transpire, although their photosynthetic rate is low due to reduced light. Marangoni *et al*., (1992) showed that the stomatal conductance of shaded leaves may be up to 60% of that of exposed leaves. In apple trees in the field, it appears that stomata are well coupled with photosynthesis; usually not opening more than needed to maintain a constant internal CO_2 (Lakso, 1994). This means factors affecting photosynthesis will also affect water loss. Since water is fundamental for maintaining normal physiological activity and membrane transport processes (Jones and Tardieu, 1998), supplying it adequately is crucial for obtaining maximum productivity of horticultural crops. In addition, water plays an important role in horticultural crops, since fruits vegetables, herbs and flowers are usually sold on a fresh weight basis and yield is predominantly determined by water content (Marcelis *et al*., 1998).

Water Stress Effect on Fruits

Limited water supply (LWS) is a serious threat to agriculture, and often cause yield and quality reduction in crops (Wang & Frei, 2011). According to a study conducted by Miller *et al*., (1998), a significant fruit weight loss was observed in kiwi fruit (*Actinidia deliciosa* cv. Hayward) exposed to water stress during fruit set period. In contrast, they observed an increase in the total soluble solids. Bordonaba & Terry (2010), also tested the response of strawberry (*Fragaria X ananassa* Duch. cvs. Elsanta, Sonata, Symphony, Florence and Christine) to deficit water. They obtained that, different cultivars responded differently to water stress, expressing specific water usage. Berry size was equivalent (Florence and Christine) or smaller (Sonata and Symphony) than control plants. Dry mater, as proportion of fruit weight, was considerably greater in fruit plants from water stressed than from plants kept at or near field capacity. Berries from stressed plants showed lower redness than unstressed berries. Indicating that the secondary metabolites, anthocianins, content is lower in stress plants. Concerning the sugar content, the authors did not obtained significant differences among treatments. However, monosaccharides (fructose and glucose) were in higher concentrations in stressed plants, thus berries were sweeter. Acids are also important flavor components in strawberries. The result showed that, stress condition increased the acidity in all cultivars except Elsanta and Sonata. Studies conducted by Mpelasoka *et al*., (2001b) in Apple, by Lopez *et al*., (2011) in Pear, by Perez-Pastor (2007) in Apricot, by Gelly *et al.* (2003) in peach, by Intrigliolo & Castel (2010) in plum, by García-Tejero (2010) in orange, Du *et al*., (2008) in Grape and by Proietti *et al*., (2008) in Watermelon showed that water stress has a significant influence on fruit productivity and quality.

Water Stress Effect on Vegetables

Vegetables are the best resource for overcoming micronutrient deficiencies and provide smallholder farmers with much higher income and more jobs per hectare than staple crops (AVRDC, 2006). The worldwide production of vegetables has doubled over the past quarter century and the value of global trade in vegetables now exceeds that of cereals. Vegetable production environment is a mixture of conditions that varies with season and region. Drought or reduced irrigation water availability, flooding, and salinity will be major limiting factors in sustaining and increasing vegetable productivity (Hughes, 2007). Vegetables, being succulent products by definition, generally consist of greater than 90% water (AVRDC, 1990). Thus, water greatly influences the yield and quality of vegetables. Drought conditions drastically reduce vegetable productivity. Drought stress causes an increase of solute concentration in the environment (soil), leading to an osmotic flow of water out of plant cells. This leads to an increase of the solute concentration in plant cells, thereby lowering the water potential and disrupting membranes and cell processes such as photosynthesis. The timing, intensity, and duration of drought spells determine the magnitude of the effect of drought. As indicated by different researchers, water-stress/ drought affect quality of vegetables.

A study conducted by Bejarano *et al*., (2000) on drought-tolerant potato (*Solanum tuberosum* L.) showed that an increased content of glycoalkaloids (GAs, α-solanine and α-chaconine) under drought stress. According to the authors, under drought stress conditions GAs concentration increased on average by 43% and 50% in the improved and control cultivars, respectively. GAs are natural toxins synthesized by plants of the Solanaceae family and are believed to be associated with resistance to certain insects. At least 95% of total GAs are in the form of α-solanine and α-chaconine. Both compounds are heat-stable and therefore are not destroyed by common cooking processes such as boiling or frying (Friedman, 2006). Another study conducted by Sánchez-Rodríguez *et al*., (2011) on Tomato plants (*Solanum lycopersicum* L.), cultivars Kosaco, Josefina, Katalina, Salomé and Zarinas, showed a decreased phenolic compounds under water stress in all of the studied cultivars except Zarinas. This showed that water availability affects the synthesis of secondary metabolites of plants 'Phenolic compounds' that are frequently associated with beneficial effects in human health (Dixon & Paiva, 1995; Hooper & Cassidy, 2006). Similarly, influence of water on productivity and quality were reported for eggplant (Solanum melongena L.) cv. Pala by Kirnak *et al.*, (2002), for Broccoli by Cogo *et al*., (2011) and for Lettuce by Coelho *et al*., (2005). An investigation by Schreiner *et al.,* (2009) on Ethiopian mustard (*Brassica carinata*), lines Holeta-1 and 37-A, to water restriction treatments showed an increases in leaf glucosinolates under low water content, leading to severe yield losses. The most important compounds with regard to flavour, pungency, bitterness and sulphurous aroma in cabbage, are also affected by water supply (Fahey *et al*., 2001; Talalay & Fahey, 2001).

Influence of Water Stress on Spice, Aromatic and Medicinal Plats

Spice, medicinal and aromatic plants are of prime economic importance because of the continuous and increasing demand for their products by local and foreign markets. In aromatic, spice and medicinal plants, growth and essential oil production are influenced by various environmental factors, such as water stress (Burbott and Loomis, 1969). Solinas and Deiana (1996) reported that secondary products of plants can be altered by environmental factors and water stress is a major factor affecting the synthesis of natural products. Changes in essential oils extracted from aromatic plants and their composition were observed with water stress (Sabih *et al*., 1999). An investigation conducted by Mirsa and Strivastava, 2000, showed that, water stress resulted in significant reduction of fresh and dry matter, nutrient content, and essential oil yield of Japanese mint plants. Simon *et al*., 1992 also reported a decrease of fresh and dry weights of *Ocimum basilicum* L. as plant water deficit increased. They also reported an increase of linalool and methyl chavicol contents of sweet basil as water stress increased. Essential oil and proline contents of sweet basil increased in response to water stress but plant growth was decreased with increasing water stress. The essential oil yield of basil was increased by subjecting plants to water stress just before harvesting (Baeck *et al*., 2001). Water stress reduced fresh and dry weights of *Satureja hortensis* L. (Savory) plants. Severe water stress in this plant increased essential oil content more than moderate water stress. The main constituents, such as carvacrol, increased under moderate water stress, while ã-terpinene content decreased under moderate and severe water stress of *Satureja hortensis* L. (Baher *et al*., 2002). Hendawy and Khalid, (2005) stated that essential oil, total carbohydrate, and proline contents were pronouncedly increased with increasing stress levels of *Salvia officinalis* L. plants.

A study conducted by Khalid, (2006), showed that, water stress treatments increased essential oil percentage, main constituents of essential oil, proline, and total carbohydrate content, but decreased N, P, K, and protein content of two Ocimum species (*Ocimum basilicum* L. and *Ocimum americanum* L.). Effects of irrigation regimes on growth, essential oil content and composition of *T. hyemalis* (Jordan *et al*., 2003) and *T. vulgaris* (Lechamo and Gosselin, 1995; Khazaiei *et al*., 2008*) is also reported*. Bahreininejad *et al*., 2013 investigated the effects of water stress on growth, chlorophyll, carotenoid, proline, K^+ contents, essential oil yield, content and composition, of *Thymus daenensis*. They obtained that, water stress reduced chlorophyll and carotenoid contents, root and shoot growth, and $IWUE_{dm.}$ However, the contents of proline, K^+ and essential oil and $IWUE_{eso}$ of *T. daenensis* were increased. Astudy by Said and Hussein, (2010) showed that herbal production and essential oil content of *Origanum vulgare* L. can be significantly affected by soil moisture content. A study conducted by Phimchan *et al*., (2012) in Hot peppers (*Capsicum spp*.) showed that drought stressed plants expressed a significant decrease in leaf water potential, leaf area, shoot-to-root ratio, and dry fruit yield. Similarly a study conducted by Riaz *et al*., (2013) on Marigold showed that water stress significantly influences physiological parameters such as net CO_2 assimilation rate (Pn), transpiration rate (E), stomatal conductance (gs), sub-stomatal conductance, leaf water potential, water use efficiency Pn/E and chlorophyll content.

Influence of Flooding on Horticultural Crops

Since plant development and productivity is affected by both too little and too much water, it is important to discuss about water logging/flooding in addition to effect of water-stress. Flooding is produced by storms, over irrigation, poor drainage, high water tables and dam and river over flowing (Rao and Li, 2003). Flooding affects soils by altering soil structure, depleting O_2, accumulating CO_2, inducing anaerobic decomposition of organic matter and reducing solubility of iron and manganese (Kozlowski, 1997; Liao and Lin, 2001; Jackson and Colmer, 2005). Plants induce a series of physical, chemical and biological processes in response to flooding conditions. Plant responses to waterlogging include increased internal ethylene concentration, low stomatal conductance, decrease in leaf, root and shoot development, changes in osmotic potential and nutrient uptake, and reduced chlorophyll content and photosynthesis (Tamura *et al*., 1996; Rao and Li, 2003; Issarakraisila *et al*., 2007). Flooding also increases the severity of certain diseases, mainly root-rotting fungi (Rao and Li, 2003), as reported by De Siva *et al*., (1999) regarding Phytophthora root rot in blueberry. The decrease of oxygen level in soils affects the bioavailability of nutrients as well as the ability of root systems to uptake and transport water and mineral nutrients (Lizaso *et al*., 2001). Waterlogging caused inhibition of N uptake from the soil and reduced leaf concentrations of N, P, K, Ca and Mg in avocado (Schaffr and Andersen, 1994) and pea (Rao and Li, 2003). Iglesias *et al*., (2007) reported that, waterlogging inhibits initiation of flower buds, anthesis, fruit set, and fruit growth in citrus fruits. According to them, fruit quality is also reduced since the chemical composition and appearance of fruits is altered and the size diminished. Previous researches on similar fruit showed that excess water provokes fruit burst or crack especially when long periods of drought precede soil waterlogging (Kaufmann, 1972).

Physiological Studies Related with Temperature

Temperature influences photosynthesis, water and nutrient absorption, transpiration, respiration and enzyme activity. These factors govern germination, vegetative growth, flowering, pollen viability, fruit set, fruit ripening, rates of maturation and senescence, yield, quality, harvest duration and shelf life in horticultural crops (Sage and Kubien, 2007; Ledesma *et al*., 2008; Kositsup *et al*., 2009). Temperature is the climatic factor that, more than any other, determines the kinds of plants that will grow in an area. Photosynthesis, transpiration, and respiration increase with rising temperature. Many horticultural crops thrive in warm climates in some area but challenged in another. Cold temperatures also affect horticultural crop production by restrict plant growth, freeze plants in mid-winter, and damage plants during fall and spring frosts (Robbines and Bell, 2006). Each plant type has an optimal temperature needed for growth. Some plants prefer cooler nights or days, whereas others prefer warmer nights or days. If the temperature is below or higher than the requirements, growth and productivity affected.

Influence of High Temperature

Plant growth is measured by the food energy produced thorough photosynthesis above that used for respiration. Plants generally grow best at the higher end of their optimal temperature range. In the temperate zone, the minimum temperature for growth is about 40°F. Photosynthesis and respiration increase as temperatures rise until the energy used in respiration equals photosynthetic capacity, when growth ceases. For most plants, this temperature is around 96°F. For many cool-season crops, growth may cease at temperatures considerably lower than 96°F. Warm temperatures cause stored carbohydrate reserves to be used up thorough respiration or to be converted to starch. This affects the sweetness of crops such as sweet corn and peas and thus their quality. Very high temperatures can cause physiological damage to plants resulting in burnt leaves and slowed growth (Robbines and Bell, 2006). An investigation conducted by Abdelmageeda *et al*., (2003) on the effect of high temperature on Tomato genotypes showed that high temperature severely affects the reproductive processes of tomato than the vegetative ones. The authors also explained that the number of pollen grains produced by the heat tolerant genotypes were higher than the number of pollen grains produced by the heat sensitive genotypes. This indicated that pollen production in tomato affected by high temperature. Another study by Khanal *et al.*, (2013) also indicated influence of high temperature on fruit firmness, dry matter content, soluble solids, titratable acids, and pH of Tomato. Harel *et al.,* (2014) also reported 25–26°C of mean daily temperature for best pollen quality, fruit set rates and fruit yield of tomato. Their research revealed that mean daily temperatures of 25–26°C are the upper limit for proper fruit set and fruit yield for tomatoes grown in protected cultivation. A study conducted by Rykaczewska, (2013) to assess the response of potato cultivars to high temperature during the different stages of plant growth showed that, productivity of potato greatly reduced at higher temperatures than the optimum temperatures. He also explained that the influence of high temperature is more pronounced at early growth stage in all the studied cultivars and reduced the yield by 50% and 25% in susceptible and tolerant cultivars, respectively. Therefore, higher temperature affects the yield of both tolerant and susceptible cultivars. Influence of different temperatures (20, 25, 30, 35, 40 and 45°C) on seed germination of black pepper (*Piper nigrum* L.) was investigated by Li *et al*., (2010) and showed that the optimum germination temperature for black pepper is 30 to 35°C. They also reported that black pepper seed did not germinate at temperature of < 20°C and > 40°C.

Influence of Low Temperature

Many plants are susceptible to frost and cold temperatures. If temperatures are too cool, there will be a lack of plant growth, a failure of seed germination, and some plants will not set fruit. Plants have a minimum survival temperature below which they will be severely injured or killed. The amount of plant damage depends on many variables such as the kind of plant, the plant part, the nutrients and moisture in the plant tissues, the season of the year, the temperature during the freeze, the temperature after the freeze, the amount of air movement, and the moisture level in the soil (Robbines and Bell, 2006). Cooler temperature also induces premature flower stalk formation and development of winter hardiness or dormancy. A research conducted on Avocado from different origin shows that, West Indian avocado trees are the most cold sensitive and are damaged by temperatures below 1.2°C while the Mexican race is the most frost tolerant. Mature trees are capable of withstanding temperatures as low as -4°C without damage (Joubert and Bredell 1982). Sedgley and Grant (1982) also reported, influence of low night temperatures below 12°C on flowering and fertilization of avocado. Cool temperatures will also reduce insect activity resulting in less pollination (Bergh 1967; Peterson 1955). Lahav and Trochoulias (1982) noted that cool temperatures promoted root growth and dry matter accumulation, both of which suffer at higher temperatures. Davenport (1986) observed that cooler temperatures facilitated "self-pollination" due to a partial overlapping of the male and female phases of each flower. An investigation conducted on citrus fruit showed that cooler temperature induces abortion of development of inflorescences; reduction of fertility and fruit set; arrest of leaf and fruit growth; and abscission of reproductive and vegetative structures including buds, flowers, ovaries, developing fruitlets, ripe fruits and leaves (Iglesias *et al*., 2007). Hu *et al*., (2006) conducted a research to see the influence of low temperature on cultivated tomato genotype (*Solanumlycopersicum*, earlier known as L *ycopersicon esculentum* L.). According to the authors, tomato genotypes display limited growth and development at temperatures below 12ºC. They also showed that at temperatures between 0 and 12ºC, plants are damaged by the chilling stress and the severity of damage is proportional to the length of time spent in this temperature range. Generally, the studies reviewed above showed that, physiological process of horticultural crops affected by both high and low temperature.

Physiological Studies Related with Light

Light is a form of electromagnetic radiation that is visible to the human eye. Sunlight is essential for any crop and dry matter production often increases in direct proportion with increasing amounts of light. The amount of sunlight received by plants in a particular region is affected by the intensity of the incoming light and the day length. The light intensity changes with elevation, latitude, and season, as well as other factors such as clouds, dust, smoke, or fog. The total amount of light received by a crop plant is also affected by cropping systems and crop density. Different plants differ in their light requirements (Argus Control Systems Ltd, 2010). Sunlight is not only the energy source for photosynthesis, but also the most important factor affecting productivity in horticultural crops (Gregoriu *et al*., 2007). Carbon exchange rate (CER) is strongly dependent on irradiance, absorption, and utilization of photon energy (Jackson, 1980; Gregoriu *et al*., 2007). The intensity, quality and duration of the daily light that plants receive all affect photosynthesis and, hence, affect plant growth (Stadler, 2010).

Light Intensity

Light intensity needed for the maximum rate of photosynthesis is quite distinct, depending on plant cultivars and ambient conditions. Too low light intensity cannot satisfy the requirement of photosynthetic capacity and thus results in insufficient synthesis of photo assimilates, which severely influences plant growth, development, and yield. On the contrary, too high light intensity may cause significant decline in the photochemical activity of photosystem II or photosystem I, which is known as photo inhibition (Murata *et al*., 2007; Kreslavski *et al*., 2007). It usually occurs when the light-dependent reactions of photosynthesis produce ATP and NADPH in excess of that can be consumed by the reactions of dark carbon metabolism (Li *et al*., 2009). Healthy leaves growing under favorable conditions can experience intense light without extensive photo damage (Govindacharya *et al*., 2004). However, when the environmental conditions do not promote carbon fixation, even weak or moderate light may become harmful (Gerotto *et al*., 2011).

Light Quality

Light quality is thought to affect many plant physiological processes during growth and development, particularly photosynthesis and morphology. Light quality alters plant photosynthesis by the effects on the activity of photosynthetic apparatus in leaves and the effects on the expression and/or activity of the Calvin cycle enzymes (Wang *et al*., 2009). Cucumbers grown under monochromatic light, including purple, blue, green, yellow and red, have reduced growth, CO_2 assimilation rate and quantum yield of photosystem II electron transport as compared with plants grown under white, and these reductions are more significant in the plants under green, yellow and red. Interestingly, plants grown under purple and blue have higher stomatal conductance, total and initial Rubisco activities and higher transcriptional levels of genes encoding key enzymes in the Calvin cycle together with higher total soluble sugars, sucrose and starch contents as compared with plants grown under white, whereas in plants grown under green, yellow and red, these parameters decline. Yu and Ong, (2003) reported that the CO_2 assimilation rate, dark respiration, total biomass and relative growth rate of seedlings grown under monochromatic radiation were significantly lower than those of seedlings grown under broad spectrum light (Allen *et al*., 1997).

Light Duration/ Photoperiod

Photoperiod can also influence plant growth and development, especially sex expression. Floral Induction and differentiation, the most important developmental transition from vegetative growth to reproductive growth in life cycle of higher plants, can directly affects the agricultural yield through determining the time of flowering, the number of flowers and fruits, as well as the diversion of resources from vegetative growth (Terefe, and Tatlioglu, 2005; Chen *et al*., 2011). Longer photoperiod can increase the daily integrated photosynthetic photon flux and more photosynthetic product can thus be synthesized and possibly release the carbohydrate competition between vegetative organs and reproductive organs. There have been many reports on effects of photoperiod on sex expression in horticultural crops such as cucumber, a model plant often used for sex expression research in flowering plants (Miao *et al*., 2011). The number of pistillate flowers is increased under short photoperiod in monoecious cucumber (Astmon, and Galun, 1962) and in an androecious cucumber (Rudich *et al*., 1976). However, Cantliffe, (1981) reported that photoperiod had no effects on sex expression in cucumber and gherkin. Jutamanee *et al*. (1994) reported that the influence of photoperiod on sex expression depended on the genetic background. The short day treatment promotes pistillate flower formation and suppresses staminate flower formation in monoecious cucumbers due to the increased evolution of endogenous ethylene (Yamasaki *et al*., 2003) whereas the long day treatment has the reversed effect (Wu *et al*., 2010). Photoperiod has no significant effects on sex expression in gynoecious cucumbers. Photoperiod can influence leaf senescence as well. Many studies have suggested that leaf senescence occurred as a consequence of shorter photoperiod, whereas extended photoperiod delayed leaf senescence (Zhao *et al*., 2009). This evidence suggests that it is necessary to take both light intensity and photoperiod into consideration as supplemental lighting is applied for crop production in protected farmland. Several researches were conducted concerning light and horticultural crops production. Some of them are discussed below.

The influence of artificial lighting on plant growth, yield and quality of tomatoes (Demers *et al*., 1998), cucumbers (Hao & Papadopoulos, 1999) and sweet pepper (Demers & Gosselin, 1998) has been studied. Photoperiod recommendations for different species have been proposed and the optimal growth and yields of sweet pepper for instance were obtained under photoperiods of 14 and 20 hours, respectively (Demers & Gosselin, 1998). It is often assumed that an increment in light intensity results in the same yield increase. Marcelis *et al*., (2006) found that a 1 % light increment results in an increase in yield of 0,7-1 % for fruit vegetables. Demers *et al*., (1991) reported that biomass, early and total yield of sweet pepper, number of harvested fruits and the average weight were increased at 125 µmol/m^2/s (approx. 25 W/m2) compared to 75 µmol/m2/s (approx. 15 W/m2). Stadler, (2010) reported that, productivity of sweet pepper can enhanced by distributing a higher amount of light intensity. At low natural light level, the yield was higher at higher light intensities whereas at low light intensities, stem density did not influence yield. However, with a higher light intensity it was advantageous to have a higher stem density. This is indicating, that higher light intensities allow for the increase of stem density. Similar result was also obtained by Dorais *et al*., (1991). A study conducted by Bergstrand and Schüssler, (2012) on Growth and Photosynthesis of Ornamental Plants Cultivated under Different Light Sources shows, shoot elongation was highest for plants grown under HPS lamps, as was fresh weight. Measurements of photosynthesis under the different light sources revealed a trend for higher photosynthesis when white LEDs were used. However, when photosynthesis was measured at different light intensities using red/blue LEDs, plants grown under HPS lamps had the highest photosynthesis. The air temperature in the canopy was lower when the light was supplied with LEDs than with HPS lamps, thus delaying development. The author concluded that the quality of light supplied was a significant factor for plant development in greenhouse conditions with supplementary light.

The influences of three different qualities of light (red, blue, and white) on plant biomass and accumulation of chlorophylls (chl), carotenoids (car), soluble proteins and sugars, and nitrates in the leaves of lettuce (*Lactuca sativa* L. var. capitata) was also conducted by (Lin *et al*., 2013). They reported that, light quality has a significant influence on growth, nutritional quality and marketable properties of lettuce. Shoot FW and DW, and root FW and DW of the plants were greatest when grown under RBW light, and lowest under RB light. The soluble sugar content in plants was highest under RBW treatment but the nitrate content of lettuce plants was significantly lower in the RBW treatment than those of plants under RB treatments. Concerning marketable properties, plants under RBW light treatment had high grades of all of the parameters (Shape, color, crispness, and sweetness). The effects of different light intensities on anti-oxidative enzyme activity, yield and quality of lettuce were also investigated by Fu *et al*., (2012**)** and they reported that the range of 400 to 600 µmol/m^{2}s is a recommendable light intensity for lettuce production. Kotiranta, (2013) also reported significant influence of light quality on morphology and stomatal function of tomato plants. Another study conducted by Yoshida *et al*., (2012) on effects of light quality and light period on the flowering of ever bearing strawberry show that blue light advances the flowering of ever bearing strawberry plants compared to red light. Haque *et al*., (2009) evaluated morphological, physiological and yield of cucumber under different light intensities (100, 75, 50 and 25% PAR). The result shows that cucumber produced the highest yield (15.32 t ha 1) at full sunlight. Considering TDM and fruit yield cucumber were found suitable for reduced light condition up to 50% PAR. Similarly influence of light was reported by Mata, (2009) on poinsettia plant, by Sase *et al*., (2012) on leafy vegetables and by Verheul, (2012) on tomato. As it can be seen from the points discussed above, light quality, quantity and duration has an influence on production of horticultural crops.

CONCLUSION

As it can be understand from the discussed points above, agriculture in general and horticultural production in particular is highly affected by the major environmental factors such as light, temperature and water availability. This paper review some of the researches conducted on these environmental factors. It cannot be say all of the previous works are reviewed exhaustively. Also there are so many remaining issues that should be addressed in the future concerning long term integrated abiotic stress management program, selection of suitable varieties, further investigations on other physiological and agronomical aspects of different horticultural crops, improving lighting design to increase efficiency of artificial light and decrease electricity cost in protected horticulture, increasing irrigation efficiency and so on.

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