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A review on the pollution and its impact on horticultural crops

Vinay Joseph Silas and Vijay Bahadur

Abstract

The Horticulture production deals with the intensive use of resources like land, water, labour and fertilizers. The use of such resources in limited period and time potential to negative impact on the environment. Plants are exposed to many stress factors, such as drought, high salinity or pathogens, which reduce the yield of the cultivated plants or affect the quality of the harvested products. This paper deals with the overview of the pollution which is caused by the different sources such as increased level of CO2, industrial waste, including the impact of stress in horticulture crops, physiological and biochemical factors associated with stress.

Keywords: pollution, stress, horticulture crops and environment

Introduction

Pollution is defined as the introduction into the environment of substances harmful to humans and other living organisms. Pollutants are harmful solids, liquids, or gases produced in higher than usual concentrations that reduce the quality of our environment. Human activities have an adverse effect on the environment by polluting the water we drink, the air we breathe, and the soil in which plants grow. Although the industrial revolution was a great success in terms of technology, society, and the provision of multiple services, it also introduced the production of huge quantities of pollutants emitted into the air that are harmful to human health. Without any doubt, the global environmental pollution is considered an international public health issue with multiple facets. Social, economic, and legislative concerns and lifestyle habits are related to this major problem. Clearly, urbanization and industrialization are reaching unprecedented and upsetting proportions worldwide in our era. Anthropogenic air pollution is one of the biggest public health hazards worldwide, given that it accounts for about 9 million deaths per year WHO Air Pollution 2019) [72]. Without a doubt, all of the aforementioned are closely associated with climate change, and in the event of danger, the consequences can be severe for mankind (Moores FC 2009) [47]. Climate changes and the effects of global planetary warming seriously affect multiple ecosystems, causing problems such as food safety issues, ice and iceberg melting, animal extinction, and damage to plants (USGCRP (2009) [68], Horticultural production is primarily involved in the intensive use of resources, suchas land, water, labour and inputs such as fertilisers and pesticides. The use of such resources in a concentrated space and time has the potential to negatively impact on the local environment and worker welfare. In addition the transport of horticultural produce over long distances, particularly by air transport, and reported in term of food miles, is known to have a negative contribution to the global environment (H. Wainwright *et al.* 2014) [30].

Environmental Threats

Land

Land occupied by the horticultural industry is limited and to sustain crop productivity it is essential that it is maintained as a fertile and productive resource. Intensive agricultural and horticultural practices over the twentieth century, coupled with growing greenhouse production, have dramatically impacted on the horticultural landscape. Land and soil degradation caused by erosion (wind and water), organic matter decline, compaction, salinization, reduced fertility and pollution all have the potential of environmental mismanagement within horticulture. This in turn leads to degradation and as a result impede on the biosecurity of future production (H. Wainwright *et al.* 2014) [30].

Water

Agriculture and horticulture combined is the largest user of freshwater, accounting for 70% of all bluewater withdrawals (Fischer *et al.* 2007) [28] worldwide and is mainly used for irrigation. Climate change and population predictions warn of a global reduction in freshwater availability and an increase in demand (Falloon and Betts 2010) [25]. By 2030 there is an expected 40% shortfall between supply and demand for freshwater (Anon 2012a) [7].

Fertilisers

Intensive crop production requires higher levels of inorganic fertilisers. As horticultural crops are usually high value, the relative cost of these inputs to producers is less important and as a result they may be applied in excess; consequently increasing the risk of land and water pollution (H. Wainwright *et al.* 2014) [30].

A central environmental impact on water quality and human health is excessive nitrate levels. Nitrogen fertilisers which leach into the ground and runoff into water courses contaminate surface water. Excessive nitrate (NO3) in drinking water is associated with an illness of infants under 6 months' old called methemoglobinemia or "blue-baby" syndrome (Knobeloch *et al.* 2000) [36].

Another process is eutrophication which often takes place when contamination from nitrate and phosphate fertilisers occurs in aquatic ecosystems, both fresh and saltwater. The process derives from increased algal production accelerated by elevated nitrogen deposits (including nitrate and ammonia) within the water. This can cause hypoxia- suffocation- of aquatic life beneath the water surface, disrupting bio diverse ecosystems and promoting the development of nuisance algae (National Research Council 2000) [48].

Labour

An important feature of horticultural enterprises is their intensive use of labour. Economic migration to concentrated areas of horticultural activity benefits communities in terms of high employment rates but simultaneously increases demand on natural resources and social infrastructure. Rapid population growth resulting from expansion of the floriculture industry in Lake Naivasha, Kenya has caused unregulated urbanisation, decreased the quality of peri-urban land, overloaded sewage systems and increased local pollution. Excessive extraction of water from the lake for industrial and residential use has contributed in association with a drought to a decline in water levels. In 2010 the lake receded to its lowest recorded level since the 1940s (Harper *et al.* 2011) [32]. Over-exploitation of the water resource is contributing to reduced biodiversity, threatening future water security and local ecosystems which are already endangered by the introduction of invasive species.

Increased level of CO2

Atmospheric concentrations of carbon dioxide have been steadily rising, from approximately 315 ppm (parts per million) in 1959 to a current atmospheric average of approximately 385 ppm (Keeling *et al.*, 2009) [35]. Current projections are for concentrations to continue to rise to as much as 500–1000 ppm by the year 2100 (IPCC 2007) [33].

While a great deal of media and public attention has focused on the effects that such higher concentrations of CO_2 are likely to have on global climate, rising CO_2 concentrations are also likely to have profound direct effects on the growth, physiology, and chemistry of plants, independent of any effects on climate (Ziska 2008) [73]. These effects result from the central importance of CO_2 to plant metabolism. As photosynthetic organisms, plants take up atmospheric CO_2, chemically reducing the carbon. This represents not only an acquisition of stored chemical energy for the plant, but also provides the carbon skeletons for the organic molecules that make up a plants' structure. Overall, the carbon, hydrogen and oxygen assimilated into organic molecules by photosynthesis make up ~96% of the total dry mass of a typical plant (Marschner 1995) [45]. Photosynthesis is therefore at the heart of the nutritional metabolism of plants, and increasing the availability of CO_2 for photosynthesis can have profound effects on plant growth and many aspects of plant physiology.

One of the most consistent effects of elevated atmospheric CO_2 on plants is an increase in the rate of photosynthetic carbon fixation by leaves. Across a range of FACE experiments, with a variety of plant species, growth of plants at elevated CO_2 concentrations of 475–600 ppm increases leaf photosynthetic rates by an average of 40% (Ainsworth & Rogers 2007) [6]. Carbon dioxide concentrations are also important in regulating the openness of stomata, pores through which plants exchange gasses, with the external environment. Open stomata allow CO_2 to diffuse into leaves for photosynthesis, but also provide a pathway for water to diffuse out of leaves. Plants therefore regulate the degree of stomatal opening (related to a measure known as stomatal conductance) as a compromise between the goals of maintaining high rates of photosynthesis and low rates of water loss. As CO_2 concentrations increase, plants can maintain high photosynthetic rates with relatively low stomatal conductance. Across a variety of FACE experiments, growth under elevated CO_2 decreases stomatal conductance of water by an average of 22% (Ainsworth & Rogers 2007) [6]. This would be expected to decrease overall plant water use, although the magnitude of the overall effect of CO_2 will depend on how it affects other determinants of plant water use, such as plant size, morphology, and leaf temperature. Overall, FACE experiments show decreases in whole plant water use of 5–20% under elevated CO_2. This in turn can have consequences for the hydrological cycle of entire ecosystems, with soil moisture levels and runoff both increasing under elevated CO_2 (Leakey *et al.* 2009) [39].

Since photosynthesis and stomatal behavior are central to plant carbon and water metabolism, growth of plants under elevated CO_2 leads to a large variety of secondary effects on plant physiology. The availability of additional photosynthate enables most plants to grow faster under elevated CO_2, with dry matter production in FACE experiments being increased on average by 17% for the aboveground, and more than 30% for the belowground, portions of plants (Ainsworth & Long 2005; de Graaff *et al.* 2006) [5, 20]. This increased growth is also reflected in the harvestable yield of crops, with wheat, rice and soybean all showing increases in yield of 12–14% under elevated CO_2 in FACE experiments

Elevated CO_2 also leads to changes in the chemical composition of plant tissues. Due to increased photosynthetic activity, leaf non-structural carbohydrates (sugars and starches) per unit leaf area increase on average by 30–40% under FACE elevated CO_2 (Ainsworth 2008; Ainsworth & Long 2005) [4]. Leaf nitrogen concentrations in plant tissues typically decrease in FACE under elevated CO_2, with nitrogen per unit leaf mass decreasing on average by 13% (Ainsworth & Long 2005) [5]. This decrease in tissue nitrogen is likely due to several factors: dilution of nitrogen from increased carbohydrate concentrations; decreased uptake of minerals from the soil, as stomatal conductance decreases and plants take up less water (Taub & Wang 2008) [64]; and decreases in the rate of assimilation of nitrate into organic compounds (Bloom *et al.* 2010) [13].

Protein concentrations in plant tissues are closely tied to plant nitrogen status. Changes in plant tissue nitrogen are therefore likely to have important effects on species at higher trophic levels. Performance is typically diminished for insect herbivores feeding on plants grown in elevated CO_2 (Zvereva & Kozlov 2006) [74]. This can lead to increased consumption of plant tissues as herbivores compensate for decreased food quality (Stiling and Cornelissen 2007) [62]. Effects on human nutrition are likely as well. In FACE experiments, protein concentrations in grains of wheat, rice and barley, and in potato tubers, are decreased by 5–14% under elevated CO_2 (Taub *et al.* 2008) [65]. Crop concentrations of nutritionally important minerals including calcium, magnesium and phosphorus may also be decreased under elevated CO_2 (Loladze 2002; Taub & Wang 2008) [42, 65].

Industrial waste

Agricultural-based industries produced the vast amount of residues every year. If these residues are released to the environment without proper disposal procedure that may cause to environmental pollution and harmful effect on human and animal health. Most of the agro-industrial wastes are untreated and underutilized, therefore in maximum reports it disposed of either by burning, dumping or unplanned landfilling. These untreated wastes create different problems with climate change by increasing a number of greenhouse gases. Besides this, the use of fossil fuels also contributing the effect on greenhouse gases (GHG) emission (Bos and Hamelinck 2014) [15]. So, now it is a worldwide concern to dictating the improvement of alternative cleaner and renewable bioenergy resources (Okonko *et al.* 2009) [52]. For examples, the juice industries produced a huge amount of waste as peels, the coffee industry produced coffee pulp as a waste, and cereal industries produced husks. All over the world approximately 147.2 million metric tons of fiber sources are found, whereas 709.2 and 673.3 million metric tons of wheat straw residues and rice straws were estimated, respectively, in the 1990s (Belewu and Babalola 2009) [11]. As per the composition of these agro-industrial residues are concerned, they have high nutritional prospective, therefore they are getting more consideration for quality control and also categorized as agro-industrial by-products (Graminha *et al.* 2008) [29].

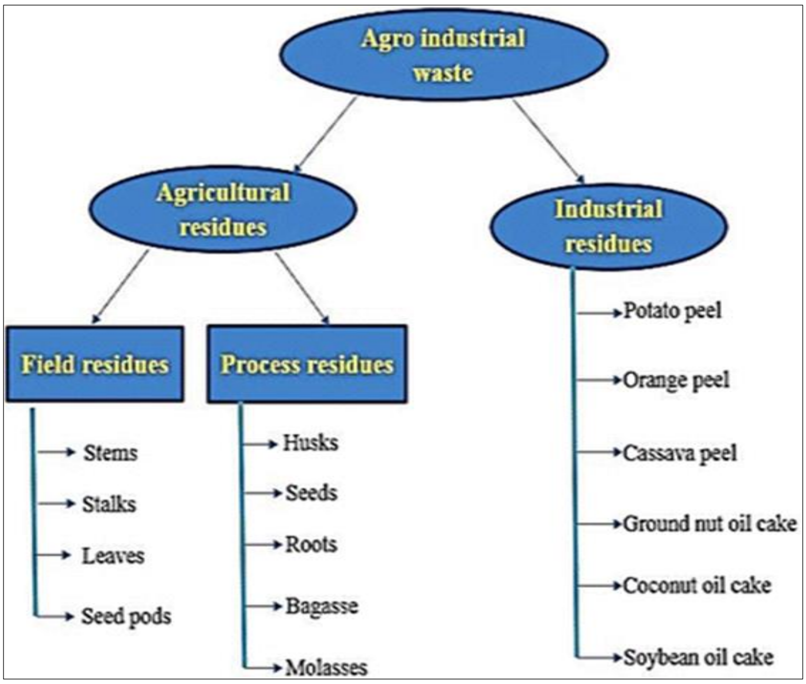
Various studies reported that different kinds of waste such as pomegranate peels, lemon peels and green walnut husks can be used as natural antimicrobials (Adámez *et al.* 2012) [2]. Wastes from the organic compounds although a risk to the atmosphere, but they represent a possible source for making of mushrooms as foodstuffs and other bio-based products like bio-energy and biofertilizers. Some of the agricultural residues are used for animal food. However, such wastes contain variability in composition like high amount of proteins, sugars, and minerals. Due to high nutritional composition, these residues not described as "wastes" but considered as raw materials for other product formation and developments. The availability of these nutrients in raw materials offers appropriate environments for the growth of microorganisms. These microorganisms have got the ability to reuse the raw materials with the use of fermentation processes. The agro-industrial residues are used for solid support in SSF developments for making different beneficial products. It also helps for the production of fermentable sugars by reducing the production cost on the basis of food crops. Various studies were carried out to know the conversion of agricultural waste into sugars by using different microorganisms (Nguyen *et al.* 2010) [49].

Type of Agro-Industrial Waste

Agriculture residue

Table 1. Shows two different types of agro-industrial wastes, i.e., agriculture residues and industrial residues. Agriculture residues can be further divided into field residues and process residues. Field residues are residues that present in the field after the process of crop harvesting. These field residues consist of leaves, stalks, seed pods, and stems, whereas the process residues are residues present even after the crop is processed into alternate valuable resource (Table 1).

Table 1: Type of Agro-Industrial Waste



These residues consist of molasses, husks, bagasse, seeds, leaves, stem, straw, stalk, shell, pulp, stubble, peel, roots, etc. and used for animal feed, soil improvement, fertilizers, manufacturing, and various other processes. Huge amount of field residues are generated and most of them are underutilized. Controlled use of field remains can enhance the proficiency of irrigation and control of erosion. In Middle East region, wheat and barley are the major crops. In addition to this, various other crops like rice, lentils, maize, chickpeas, fruits, and vegetables are also produced all over the world. Agricultural residues are differentiated on the basis of their availability as well as characteristics that can be different from other solid fuels like charcoal, wood, and char briquette (Zafar 2014) [75].

Industrial wastes

A huge amount of organic residues and related effluents are produced every year through the food processing industries like juice, chips, meat, confectionary, and fruit industries. These organic residues can be utilized for different energy sources. As the population increases continuously, the requirement of food and their uses also increased. So, in most of the countries, different industries of food and beverage have increased remarkably in that region for fulfilment of need of food. Table 2 shows different compositions of fruit industrial wastes that constitute the different compositions of cellulose, hemicellulose, lignin, moisture, ash, carbon, nitrogen, etc. and these constituents have potential to biochemically digested to produce useful products like production of biogas, bio-ethanol, and other commercially useful examples. Approximately, 20% of the production of fruits and vegetables in India are going waste every year (Rudra *et al.* 2015) [76] because in India a large amount of apple, cotton, soy bean, and wheat are produced. So as the production increased in the country, it also increased the percentage of waste produced from them. Similarly, the waste produced from food industries contains high value of BOD, COD, and other suspended solids. Most of these wastes are left unutilized or untreated, which caused adverse effect on environment as well as human and animal health but the composition of these wastes contains a large number of organic compound that produced a variety of value-added products and also reduced the cost of production.

Table 2: Composition of Fruit Industrial Waste.

Fruit-industrial waste	**Chemical composition (% w/w)**							
	Cellulose	**Hemi-cellulose**	**Lignin**	**Ash**	**Total solids**	**Moisture**	**Total carbon**	**Total nitrogen**
Potato peel waste	2.2%	–	–	7.7%	–	9.89	1.3%	–
Orange peel	9.21%	10.5%	0.84%	3.5%	–	11.86	–	–
Coffee skin	23.77 (g/100 g)	16.68 (g/100 g)	28.58 (g/100 g)	5.36 (g/100 g)	–	–	C/N 14.41	
Pineapple peel	18.11	–	1.37		93.6	91	40.8	0.99

Impact of Abiotic Stresses

Though specific agro-ecological regions are sustaining the cultivation of fruit crops as niche areas, the variability in weather conditions during critical stages of crop growth and development causes heavy yield loss and affect fruit quality. Fruit crops face various abiotic stresses like high temperature, excess and limited moisture, and salinity stresses. These stresses occurring, either at intermittent or terminal stages of crop growth, in an agroecological zone play very significant role in determining phenology, growth, development, and consequently the productivity of horticultural crops. Global warming is likely to increase the frequency, intensity, and duration of excess and limited water and high temperature stresses (Bates *et al.* 2008) [9].

Climate change, with its influence on hydrological cycles leading to changed precipitation pattern, may affect the crop production than increases in temperature. The elevated temperatures would hasten plant transpiration and soil evaporation. These stresses either individually or in combination would significantly influence the production, productivity, and quality of fruit crops. Environmental stresses during different developmental stages can cause morphological, anatomical, physiological, and biochemical changes (Ahmad *et al.* 2011) [3].

Water Stress

Horticultural crops, due to high water requirement, are grown under assured irrigation conditions, and the water-limiting situations adversely affect these crops. However, the timing, intensity, and duration determine the scale of water stress effects. In mango appearance of vegetative flushes is greatly reduced during water stress period. The water stress also causes reduction in number of leaves in a flush, the flush length, and leaf water contents. In mango water stress also plays an important role in induction of flowering mainly through its influence on floral stimulus produced by mature leaves. Under tropical conditions, even though the prevailing temperatures are not as low, water stress for a brief period induces flowering (Scholefield *et al.* 1986) [59].

Through its inhibitory influence on vegetative flushing, water stress may provide more time for accumulation of floral stimulus (Schaffer*et al.* 1994) [58].

The advancement of floral bud break by nearly 2 weeks and floral bud growth and postponement in development of vegetative buds were observed under water stress (Whiley 1986; Nunez-Elisea and Davenport 1994; Schaffer *et al.* 1994) [71, 50, 58]. Another important fruit crop, grapes, encounters frequent moisture stress conditions. It undergoes several morphological and physiological changes under water stress.

Grapevines are considered as relatively tolerant to water stress due to large xylem vessels in comparison to other crops (Serra *et al.* 2013) [60]. The roots keep on growing and exploring deeper soil layers for moisture under water-limiting conditions, but under adequate water supply, these remain confined to topsoil layer (Bauerle *et al.* 2008) [10]. The vines adapt to water scarcity conditions not only by enhancing root length but also reducing the shoot growth (Hardie and Martin 2000) [31]. Higher proportion of new roots was observed in different soil layers during dry and hot seasons for increasing the water uptake (Serra *et al.* 2013) [60].

High Temperature Stress

High temperature stress is of concern in tropical and subtropical areas. It causes damages like sunburns on leaves, branches, and stems, leaf senescence and abscission, shoot and root growth inhibition, and fruit discoloration and damage (Wahid *et al.* 2007) [69]. The high temperatures encountered at various stages of crop growth and development affect various physiological processes. The plant carbon fixation through photosynthesis would largely determine the dry matter accumulation and distribution into various plant parts. Reproductive processes are also highly affected by heat stress in most plants (Wahid *et al.* 2007) [69].

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) [70].

Mango being a tropical tree, though adapted to both tropical and subtropical climatic conditions, endures a wide range of temperatures. The prevailing temperatures determine the vegetative and flowering flushes in mango. Due to episodic vegetative flushes in a mango tree, the interaction of plant and environmental factors controls the synchronization of growth phases. Higher temperatures lead to stronger vegetative bias under sufficient nutrient and water availability (Laxman*et al.* 2016) [38]. Floral induction in mango is temperature dependent (Davenport 2007) [50] and is triggered by temperatures below 16 °C (Schaffer *et al.* 1994) [58]. Floral induction occurred at 15 °C day and 10 °C night temperatures whereas vegetative induction at 30 °C day and 25 °C night temperatures (Whiley *et al.* 1986, 1991) [77, 78]. Panicles that developed during the prevailing low temperatures usually had higher proportion of male flowers (Singh *et al.* 1974) [79], and the panicles emerging late experiencing higher temperatures had higher percentage of hermaphrodite flowers (Ramaswamy and Vijayakumar 1992) [55], 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. In wine grapes, each cultivar grows in a suitable range of temperatures, and for each cultivar, it is possible to define climates for premium wine production (Jones 2008) [34]. The adaptability of cultivars enables the production of fruit crops over a relatively large range of climates. The high temperatures advance harvest times in grapes with higher sugar concentrations, low acidity, and alterations in aroma compounds. The extreme hot temperatures may affect wine aroma and color through the effects on metabolism (Mira de Orduna 2010) [80]. The high temperatures also affect banana growth and production. The leaf production and relative leaf area growth are affected beyond 33.5 °C. The relative growth rate and dry weight increment are sustained till 39.2 °C (Turner and Lahav1983). Banana 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) [66]. The prevailing high temperature episodes coinciding with critical phenophases would affect fruit crops to various magnitudes.

Salinity Stress

The area under salt-affected soils in India is 6.74 M ha with approximately 2.95 and 3.79 M ha saline and sodic soils, respectively (Anonymous 2015b) [81]. In climate change situations, the crops would further be affected by salinity stress due to accumulation of higher amounts of salts owing to high evaporation. The higher levels of chlorides and sulfates of calcium, magnesium, and sodium present in the soils adversely cause considerable damage to many crops. These dissolved salts in the root zone cause either osmotic stress to roots, or/and when taken up, the salt ions cause toxicity to plants. The accumulation of toxic ions in leaves leads to nutrient imbalance and lower uptake of major nutrients. This results in injury to leaves, inhibition of growth, lack of fruit bearing, and consequently reduces yields.

Studies have shown that the saline conditions are not favorable for successful mango cultivation. The increase in irrigation water salinity caused the reductions in N, K, Ca, and Mg contents in leaves without affecting the contents of P and S. In banana, salt stress-induced necrosis is seen first in leaf margins and subsequently spreads to inner parts of the leaf. The salinity stress causes reduction in pseudostem thickness, delayed flowering, reduced finger size, and low-quality bunches (Ravi and Vaganan 2016) [82]. In grapes, also many physiological parameters, growth, and nutrient uptake are affected under salinity stress (Bybordi 2012) [18]. The papaya seedling growth was not affected at 2 dS m−2, growth was reduced by 50 per cent at 4 dS m−2, and mortality occurred at salinity levels >6 dS m−2 (Makhija and Jindal 1983) [43]. Therefore, fruit crops respond differently to salinity stress and are affected to various degrees at different levels of salinity.

Physiological and biochemical factors associated with Stress Management

Horticultural plants require certain physical, chemical and biological factors for their growth, development and economic production. Any deviation from these factors may cause aberrant metabolic changes in plant which reduce crop yield. Plant stresses are broadly classified into two categories i.e. abiotic and biotic stress. Abiotic stress includes physical (water deficit, flooding, temperature, radiation, mechanical, electrical and magnetic etc.) and chemical (air pollution, allelochemicals, nutrients, pesticides, toxins, salts, pH of solution) factors while biotic factors are insect, pest, disease, microbes, competition between plants, allelopathy, lack of symbiosis and human activities. These factors cause imbalance in the natural status of environment that alter normal equilibrium and which leads to a succession of morphological, physiological, biochemical and molecular changes in plants, which unfavourably affect their growth, development and potential yield. Conversely, plants develop innate adaptations to these stress conditions with a wide range of biochemical and physiological interventions that involves the function of many genes in stress (Lisar *et al.*, 2012) [40].

Physiological Changes

A plant counters to water stress by reducing growth and photosynthesis and other plant processes in order to reduce water use. As water loss increases, leaves of some species may change color usually to blue green or whitish. Foliage begins to wilt and leaves fall off and the plant die. Drought lowers the water potential of a plant's root and abscisic acid is accumulated and ultimately stomatal closure occurs. This reduces a plant's leaf relative water content. The time required for drought stress to occur depends on the waterholding capacity of the soil, environmental conditions, stage of plant growth, and plant species. Ogbaga *et al.* (2014) [51] reported that plants growing in sandy soils with low water holding capacity are more susceptible to drought stress than plants growing in clay soils. A restricted root system will increase the rate at which drought stress develops. A root system may be restricted by competing root owing to compacted soils, high water tables and container size. A plant with high mass of leaves with respect to the root system is more prone to water stress as leaves lose water faster than water supply by the roots. Newly established orchards are susceptible to drought stress because of the poor root system development and high foliage growth in initial stage. Plants adapt to water stress through various physiological mechanisms such as changes in chlorophyll content of leaf tissue, chlorophyll and membrane stability, relative water content of tissues, osmotic potential (OA), stomatal conductance, transpiration, photosynthesis poly phenol oxidase (PPO), reactive oxygen species (ROS) and antioxidant defense.

Photosynthetic pigments

Chlorophyll is one of the major chloroplast apparatus for photosynthesis activity in plants. The decrease in chlorophyll content under drought stress has been reported and it may be the result of oxidative stress and chlorophyll degradation. The chlorophyll content of leaf tissue varies with cultivars, age of the crop, growth stages, light and temperature (Makhmudov (1983) [43] reported that moisture stress inhibited biosynthesis of the precursor of chlorophyll in wheat leaves which ultimately reduced the chlorophyll content. Chen and Creeb (1991) [83] found increased level of carotenoid content under drought conditions. The chlorophyll content of the leaf was decreased by water deficit but there was accumulation of large amount of proline in the leaf. Asharaf and Mahmood (1990) [8] reported that total chlorophyll content of the leaf declined under water stress conditions. It may be due to decreased synthesis and increased degradation of chlorophyll in leaves under water stress (Dekov *et al.*, 2000) [21].

Chlorophyll stability index (CSI)

Chlorophyll stability index (CSI) is the stress tolerance capacity of plants and measured through integrity and stability of chlorophyll. Mohan *et al.* (2000) [46] reported that high CSI value means that the stress did not have much effect on chlorophyll content of plants. Plants having higher CSI can withstand stress owing to better availability of chlorophyll, leading to increased photosynthetic efficiency under stress.

Membrane stability index (MSI)

The membrane integrity and functions is influenced by reduced water content under water stress and measured through membrane stability index. The estimation of cellular electrolytes leakage from stressed leaf tissues into an aqueous medium is measure of MSI and used for drought resistance. Crop varieties differ in dehydration tolerance by the cell membrane capacity to prevent electrolyte leakage at decreasing water content. MSI is correlated with yields under high temperature and also possibly under drought stress. Preservation of membrane integrity and functions under a dehydration stress has been used as a measure of drought tolerance by various researchers (Premachandra *et al.*, 1990) [84]. Selection for osmotic membrane stability, root length and root to shoot length ratio under osmotic stress could be instrumental in predicting the drought tolerance of genotypes (Dhanda *et al.*, 2004) [22]. One of the primary injuries caused by water stress is loss in cell compartmentation due to the disruption of membrane stability. Increased leakage of solutes is an indication of damage caused to membrane. Upadhyaya *et al.*, (1989) [85] found that the decrease in MSI estimated by taking comparative ion leakage is an indicator of membrane damage as a result of lipid peroxidation caused by reactive oxygen species (ROS).

Photosynthesis

Water stress is one of the most important environmental factors inhibiting photosynthesis (Bradford and Hsiao 1982). Tezara *et al.* (1999) [17] reported that water stress substantially alters plant metabolism, decreasing plant growth and photosynthesis and finally crop productivity. Water stress restricts diffusion of CO2 into the leaf, due to stomatal closure and inhibits of CO2 metabolism. Stress decreases the amounts of ATP, and ribulose bisphosphate found in the leaves, correlating with reduced CO2 assimilation, but the amount and activity of ribulose bisphosphate carboxylase oxygenase (Rubisco) do not correlate. Rivas *et al.* (2016) [57] suggested that the tolerant cow pea cultivar was able to maintain higher photochemical activity and leaf gas exchange during water deficit for a longer period than the sensitive cultivar, which could alleviate the stress effects to the photosynthetic machinery and improve its recovery ability. Berman and Dejong (1996) [12] reported that water-stressed peach trees with heavy crop loads had significantly reduced fruit dry weights, which were likely due to carbohydrate source limitations occurred during high carbon demands of photosynthesis.

Transpiration rate

Water stress results in loss of turgidity of guard cell along with reduction of cell size and leaf area which helps in closing of stomata and decrease in transpiration rate. The rate of transpiration is directly related to difference between water vapour concentration in the intercellular spaces of the leaf and the ambient air. Pejic *et al.* (2014) [87] concluded that the onion bulb yield under rainfed conditions (1554 kg ha-1) was significantly lower than the yield (3555 kg ha-1) recorded under irrigation conditions. Evapotranspiration rate under irrigation conditions ranged from 448.9 to 511.9 mm, while it varied from 290.2 to 393.9 mm under non-irrigation conditions.

Biological factors

Proline

Proline, an amino acid accumulates due to hydrolysis of protein under water stress conditions (Kramer, 1983) [37]. High proline accumulation during stress was noted as an adaptive mechanism by which it served as a store of nitrogen and respiratory substrates to facilitate post stress recovery (Dix *et al.*, 1986) [23]. Kala and Godara (2011) [88] found that during the stress period the total proteins decreased with increase in stress in the leaves of all the three cultivars, and the decrease was maximum in Kaithli followed by Gola, but the proline accumulation in the cultivars was increased during stress period. The proline accumulation in Gola accumulated at faster rate than Umran and Kaithli.

Reactive oxygen species (ROS)

Drought creates imbalance in light capture and its utilization, which inhibit photosynthesis and make imbalance in generation and utilization of electrons and finally results in generation of reactive oxygen species (ROS). The production of ROS in plants is an early event of plant defense response to water-stress and acts as a secondary massager to trigger subsequent defense reaction in plants. Reactive oxygen species include oxygen ions, free radicals and peroxides, by product of the normal metabolism of oxygen and play important function in cell signaling. Though, during drought, ROS levels increase considerably resulting in oxidative damage to proteins, DNA and lipids (Apel and Hirt, 2004) [1]. Highly reactive ROS can adversely affect plants by increasing lipid peroxidation, protein degradation, DNA fragmentation and causing cell death. Plants produce H2 O2 in metabolic processes and cause damage of cell oxidation function. The enzyme, catalase (CAT) eliminates H2 O2 and plays a key role in the elimination of active species of oxygen (O2 -). The free radicals (OH+, O2 -) generated during lipid peroxidation readily reacted with protein and lipid membrane causing cell damage (Elstner, 1991) [89].

Abscisic acid (ABA)

Abscisic acid syntheses is one of the first reactions of plants to water stress, stimulates ABA-inducible gene expression and cause stomata closing, in that way reducing water loss through transpiration and ultimately limits cell growth. The ethylene receptor genes are upregulated by low O2 and ethylene play a crucial role in anatomical and physiological effects during hypoxia/anoxia. During O2 depletion, ethylene accumulation down regulates ABA by inhibiting rate limiting enzymes in ABA biosynthesis and by activating ABA breakdown to phaseic acid. Water deficit is sensed by the roots inducing a signal to the shoots through xylem causing physiological and morphological changes. Several genes are regulated with osmotic stress and majority of these responsive genes can be driven by either an ABA dependent or ABA independent pathway. Some studies suggest that ethylene shuts down leaf growth very fast after the plant senses limited water availability. Ethylene accumulation can antagonize the control of gas exchange and leaf growth upon drought and ABA accumulation (Carolina *et al.*, 2015) [19].

Controlled abiotic stress management for the agriculture production

The agricultural market is constantly oriented to produce the most common crops year-round, or to exploit the lower market availability of some products in early spring or late winter for getting the highest prices. The out-of-season production is often performed in greenhouses and requires high energy consumption. Therefore, suboptimal temperatures or light conditions can represent important factors to manage for avoiding crop damage and excessive production costs. Experimental work was performed in bedding plant production in greenhouses during winter, with exposure to low-energy conditions characterized by reduced temperature and light conditions for a two-week period over a growing cycle of eight weeks. Results showed negative effects on flowering and plant growth by the addition of a two-week low-energy exposure. In particular, flowering was delayed, and reductions in flower number, plant size, and biomass were observed. The most affected crops where those that were cold-sensitive, such as impatiens (Boldt, J.K.; Altland, J.E. 2019) [14].

Further, studies should be carried out on cold tolerant species and in non-flowering species. Environmental parameters have direct effects on crop performance in different seasons and different nutrient availability. Cultivation carried out with two different lettuce cultivars in different seasons and with different nutrient availabilities showed that suboptimal growing conditions limit nutrient utilization and have effects on biomass accumulation. Secondary metabolites, which can contribute to the antioxidant capacity of lettuce, were affected by the seasons by effects on both composition of different flavonoids and in their total concentrations (Sublett, W.L.; Barickman, T.C.; Sams, C.E. 2018) [63]. Considering the overall results, higher nutrient solution concentrations should be used in spring for maximizing yield and quality in lettuce

The yield of crops is directly correlated with photosynthesis and the main factors involved in this physiological process. Water is an essential element of photosynthesis, and its availability can be directly correlated with yield and quality. Prediction models have been developed for estimating yield in different stress conditions. In this special issue, a prediction model based on evapotranspiration has been used for estimating the yield of apple under water deficit conditions Lo Bianco, R. 2019 [41]. The model was studied for apple yield estimation under three cultivation regimens: conventional irrigation, partial root zone drying, and continuous deficit irrigation.

Results showed that the model worked well for vigorous cultivars such as ‘Fuji’, while it did not perform well for cultivars like ‘Gala’ that are not able to limit water losses by closing stomates. In pepper, it was demonstrated that salinity and water availability affected the yield and quality at harvest and during postharvest storage (Fallik, E *et al.* 2019) [24]. The adaptation of crops to stressful conditions can be achieved through the selection of a suitable genotype with specific traits. Genetic improvement programs can be used for enhancing tolerance to the different stresses, but require long periods of work. In the short term, agronomic strategies can be adopted for reducing stress intensity to the crops. A compendium of old and new agronomic tools has been reported in this special issue. For each stress, specific agronomic strategies have been described for lowering their negative effects and allow crops to cope with the stressful conditions (Mariani, L.; Ferrante, A. 2017) [44].

Cold Stress and Bud Dormancy Transition

Abiotic stresses may also be utilized in some species for synchronization with the seasonal change. In many fruit tree species, cold stress and the accumulation of cold units are essential for bud differentiation. In this special issue endodormancy of almond and a putative regulatory gene, the Dormancy Associated MADS-Box (DAM), has been studied (Prudencio, Á.S. 2018) [54]. Since it is well known that temperature trends affect bud dormancy, in this study the expression of PdDAM6 was compared in warmer and colder seasons. Results indicated that the endodormancy to ecodormancy transition involved a transcriptional reprogramming, in which genes acting on dormancy maintenance would be down regulated. In almond, the expression of PdDAM6 seemed to play a crucial role.

Drought Stress and Ornamental Plants

The quality of ornamental plants depends on their visual appearance, which is defined by such factors as leaf color, size, number, and longevity. Abiotic stresses and in particular drought stress can severely affect leaf morphology and physiology during adaptation to stressful environments. These responses can have a direct impact on ornamental quality and subsequently on the commercial value of the plants. A review included in this special issue describes the physiological, biochemical, and morphological changes that ornamental plants can undergo under drought stress, and how these influence quality (Toscano, S. 2019) [67]. The most common changes that can be observed on leaves are smaller size and their orientation on the branch. Ornamental plant drought stress responses are important for their selection in relationship to their area of utilization, such as urban or peri-urban areas.

Conclusions

The past decade has seen an increasing awareness of man’s activities on the planet’s environment. The horticultural value chain has affected virtually every aspect of the environment. In addition we have seen greater advances in quantifying the impact of horticultural activity on the environment. By understanding and measuring, then scientists and growers themselves have been able ways to minimize their effect on the environment through the use of technology and management strategies. This is likely to be an on-going scenario. However the climate change we are seeing currently is as a result of practices totally outside horticulture and in future global warming and the environmental impact on horticultural production may be more important than horticulture's impact on the environment.

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