Chapter

Abiotic Stresses Management in Citrus

Zeinab Rafie-Rad, Majid Moradkhani, Ahmad Golchin, Taqi Raza and Neal S. Eash

Abstract

Citrus production is affected globally by several environmental stresses. Some citrus-producing regions suffer from severe ecological abiotic stresses, including cold, soil salinity and sodicity, extreme temperature, and drought. These abiotic stresses can alleviate the growth, fruit yield, and quality of citrus. Strategies that attempt to sustain and increase tolerance of citrus against the negative effect of abiotic stresses are the use of antiperspirant compounds, phytohormones, synthetic and natural growth regulators, soil and plant moisture retaining tools and structures, nutrition management, application of organic fertilizers, rootstocks breeding in citriculture, and others. These strategies increase the yield and growth of the plant along with the relative improvement of the fruit quality during the growth and fruiting period, increasing the absorption of water and nutrients, the extensive accumulation of osmolytes and the increase of antioxidant enzymes, changes in the amount of signaling substances, and the expression of genes under stress, increase tolerance to abiotic stresses in citrus fruits. In this review, we tried to provide a summary of the abiotic stress management in citrus by literature.

Keywords: citrus, climate change, soil salinity and sodicity, drought, extreme temperature, cold

1. Introduction

Citrus species are momentous commercial fruit crops globally and are grown in more than 140 countries around the world. Citrus consists of more than 162 species belonging to the order Geraniales, family Rutaceae, and subfamily Aurantoideae. Oranges (*Citrus sinensis* (L.) Osb.), grapefruits (*Citrus paradisi* Macf.), lemons (*Citrus limon* Burm. F.), limes (*Citrus latifolia* Tan. and *Citrus aurantifolia Swingle)*, mandarins (*Citrus reticulata* Blanco), and pummelos (*Citrus maxima* (Burm.) Merr.), are the most common types of citrus fruits that are used as fresh fruit, fruit juice, and concentrate [1, 2]. Citrus is one of the fruit culture parts with the highest production on a global scale (**Figure 1**), and China is the world's largest citrus producer with 44,063,061 tons of production per year. Brazil comes second with 19,652,788 tons of yearly production. With 14,013,000 tons of production per year, India is the

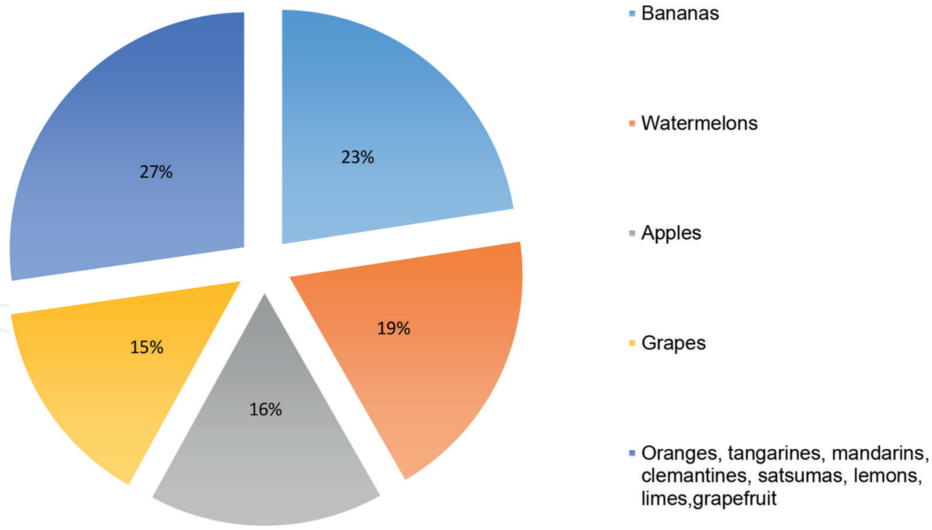

Figure 1.
Global fruit production in 2020, by selected variety (In million metric tons) [1].

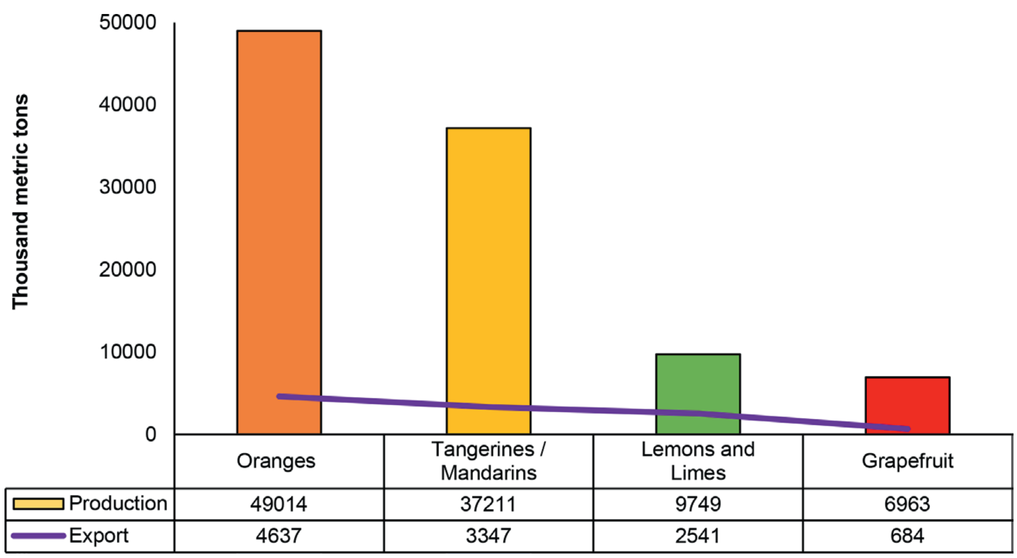

Figure 2.
Global citrus production and export quantity in 2021 [3].

third-largest producer of total citrus. Mexico with 8,756,488 tons, and the United States of America, with 7,230,854 tons of production per year are ranked 4 and 5, respectively [1].

Oranges account for half of the production and represent over 40% of world citrus exports, followed by tangerines/mandarins, lemons/limes, and grapefruit. Global exports are estimated at 11 million tons with oranges representing over 40% and tangerines/mandarins nearly 30%. Exports are propelled by tangerines/mandarins from China, South Africa, and Turkey, and to a lesser extent, higher lemon exports from Mexico, South Africa, and Turkey. South Africa is the largest exporter followed by Turkey and Egypt. U.S. citrus exports are dropping primarily due to lower orange exports. They have not been able to participate in the rising global tangerine or lemon trade due to reduced exportable supplies (**Figure 2**) [3].

Traditional citrus production methods have been successfully used over the years, and global citrus production and export have grown continuously over the past three decades. However, these methods are limited by environmental stresses, and citrus species struggle with many abiotic stresses, including cold, soil salinity and sodicity, extreme temperature, drought, and others [4].

One of the factors that cause extreme temperature, droughts, and cold, caused by severe rains and others, is climate change [5]. Global warming and climate change event have exacerbated the destructive effects of drought stress with various impacts on temperature and rainfall patterns in different areas of the world [6]. In such circumstances, water scarcity and precipitation are considered limiting factors for agriculture and crop productivity in some countries. The minus effects of abiotic stresses generally reduce tree growth, fruit yield, quality, and limit crop productivity. Under normal conditions, citrus trees mostly confront numerous stresses simultaneously, so there is a direct and indirect interplay between approximately all physical abiotic stresses. The morphological, physiological, and biochemical responses of citrus trees exposed to two or more abiotic stress factors can change, depending on stress duration or intensity. Intricate genetic responses to abiotic stresses are polygenic, making them more challenging to detect, control, and manipulate [7].

Soil salinity and drought stress are one of the main factors of yield losses in the world that can reduce the relative water content and leaf water potential. It also prevents cell enlargement more than cell proliferation. As a result, drought and salt stresses reduce plant growth and leaf area, ultimately affecting plants' photosynthesis, respiration, secondary metabolites, and carbohydrate production [4, 8]. As mentioned, climate change causes extreme temperature fluctuations, namely increase or decrease in temperature, and can cause adverse effects on plants in terms of physiology, biochemistry, and gene regulation pathways. Increased temperature causes heat stress in plants, depending on the light intensity, duration, and quality. Also, decreased temperature results in the loss of membrane integrity, leaf damage, electrolyte leakage, impaired photosynthesis, chlorophyll pigments, and protein assembly [9].

As high-temperature stress causes soil dryness and drought stress, soil waterlogging will also be stressful for the plant. Plants grow well by absorbing water through the roots and transpiration through the leaves. If the soil becomes saturated or supersaturated, waterlogging stress occurs. In this case, the leaf pores are closed, chlorophyll is lost, chlorosis is created in the leaves, and as a result, photosynthesis is reduced [10]. Stresses, such as nutrient deficiency and excessiveness, metal toxicity, and ultraviolet irradiance may occur less often, but these stresses decrease the quality and quantity of the products. Reducing the application of organic fertilizers and the imbalanced use of chemical fertilizers are the leading causes of nutritional deficiencies in plants, and we do not explain these stresses here [11]. Therefore, new production programs are essential to obtain crops more tolerant to abiotic stresses. Plant breeding programs, phytohormones, metabolic inhibitors, anti-transpiration and anti-evaporations, and plant nutrition management are critical against abiotic stress. Consequently, in this updated review, we will introduce types of abiotic stresses in citrus fruits and manage the stress tolerance of citrus by providing solutions to deal with these stresses. Hoping to provide readers with good ideas on increasing citrus fruit tolerance under abiotic stress conditions.

2. Introduction of abiotic stresses types in citrus

Citrus species, the most consumed fruit products in the world, are mainly produced in coastal areas in several countries and Mediterranean areas. Production in these areas is affected by abiotic stresses, such as drought, extreme temperature, salinity and sodicity, and others [12]. These stresses cause many reactions in the plant, including the destruction of the photosynthesis system and changes in gene expression and metabolic processes, such as increasing the synthesis of secondary metabolites and production and accumulation of reactive oxygen species (ROS) [13, 14]. It is necessary to entirely understand the reaction of citrus to abiotic stresses at different levels to apply strategies to increase stress tolerance. Plant metabolism is affected by environmental stresses, and studying at such a level is necessary for using stress-reducing compounds. **Figure 3** summarizes the adverse effects of abiotic stresses and some physiological and biochemical responses of plants to these stresses, which we will describe below.

2.1 Drought stress and its management and mitigation strategies

Citrus growth and production are affected by various environmental agents, one of which is drought. Drought, or, in other words, limited access to water is considered one of the most limiting citrus growth and production factors with adverse effects. This stress negatively affects citrus production and will be progressively more intense in some areas due to global climate changes [15, 16]. Climate change event and, consequently, global warming has exacerbated the destructive effects of drought stress with various impacts on temperature and rainfall patterns in different areas [10]. In such circumstances, water scarcity and precipitation consider limiting factors for citrus productivity in some countries, especially in Mediterranean regions.

Drought causes physiological and biochemical changes in the citrus, associated with decreased osmotic potential on the cell surface [17, 18]. Citrus growth and

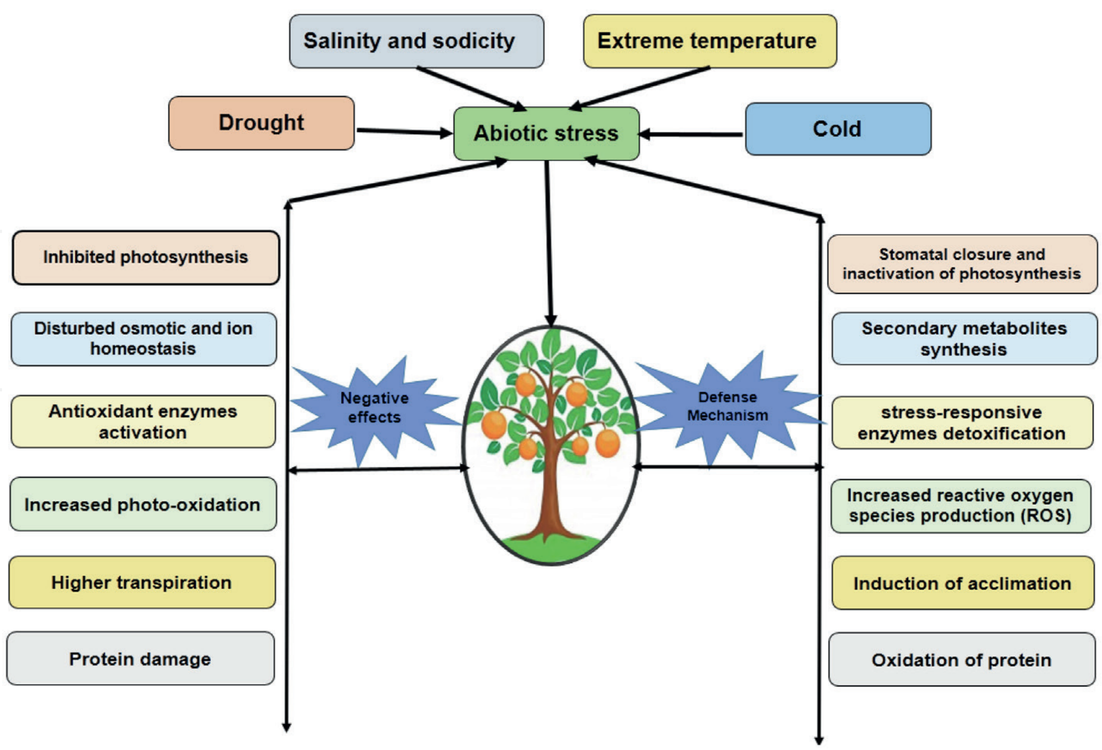

Figure 3.
It summarizes the adverse effects of abiotic stresses and some physiological and biochemical responses of plants to these stresses. Though the consequences of various abiotic stresses are different, the physiological and biochemical responses seem approximately similar. It is noteworthy that the adaptive strategies of plants against abiotic stresses are analogous (the above-summarized information is extracted from the work of [14]).

performance are decreased under drought-stress conditions by changing photosynthesis rates. Also, with the increase in the duration of drought stress, the amount of secondary metabolites changes. In this situation, osmotic pressure-regulating substances, such as proline (Pro), accumulate in the plant by spending much energy and reducing the osmotic potential. Research on lemon [19] and "Nagami" kumquat [20] leaves show a decrease in leaf water potential under drought stress conditions. Another physiological effect of drought stress in citrus is the reduction of leaf chlorophyll. In such conditions, various types of reactive oxygen species (ROS) are produced in photosystem II of photosynthesis. ROS produce compounds, such as malondialdehyde, which cause cell damage. With the accumulation of malondialdehyde, the permeability of the plasma membrane and, thus, ion leakage increases [10, 15]. The more significant influence of fruits, compared to other vegetative organs, in response to drought stress is an exciting object. Drought stress affects the quantity and quality of citrus fruit and causes a decrease in yield because available water is one of the crucial factors for increasing yield [21]. Also, in drought stress conditions, maintaining cell integration through osmotic regulation and then the accumulation of soluble solids in the fruit during the growth period increases the quality properties, such as soluble solids (SS) and titratable acidity (TA). The increase of these quality indicators in drought stress conditions has been reported in Salustiana orange fruit [22].

One of the adverse effects of drought stress in citrus is the fruit-cracking after drought stress, which is evident in citrus cultivars with navels, such as "Navel" and "Valencia" orange (*Citrus sinensis* (L.) Osbeck) and mandarin hybrids (*Citrus reticulata* Blanco). Cracked fruits are prone to decay and lose their ability to be stored. As a result, their economic value decreases. In order to reduce the bursting and the economic loss caused by it, the water required by the plant should be provided in different stages of growth [23]. Executing suitable agricultural practices is generally considered obligatory for overcoming the adverse effects of drought stress [24]. Today, advanced techniques are used in citrus production to increase the soil's water-holding capacity and improve the application of limited water resources. One of the new methods is using superabsorbent polymers (SAP) or hydrophilic polymer gels. These polymers can quickly absorb large amounts of water and gradually provide the water stored in their structure to the plant while drying the environment. In this way, the soil remains wet for a long time without rewatering [25, 26]. Modifying the citrus root system surrounded by these polymers will increase water retention and minerals in the plant growth environment, improve soil texture, increase water penetration and germination, and faster plant growth. Research conducted on Carrizo citrange and Cleopatra mandarin seedlings showed that the application of superabsorbent polymer increased water absorption and leaf chlorophyll content [25]. Superabsorbent polymers provide moisture to the soil and plants and reduce quality indicators of the fruit, such as soluble solids and titratable acidity. The results of research on sweet orange confirm these findings [27]. Another strategy proposed in recent years to deal with the harmful effects of drought stress and the high summer temperature is using antiperspirant and sunlight-reflective compounds, such as kaolin. Kaolin is a natural clay with an aluminum phyllosilicate ($Al_2Si_2O_5(OH)_4$) structure, which is chemically neutral in a wide range of pH changes and does not harm living organisms [28, 29].

High temperature causes drought stress in plants. So, net shading is another technique to improve tree water status and water use efficiency in water deficiency conditions [30, 31]. The most common shade used for this purpose is made of aluminum, polypropylene, polyethylene, and polyester, as well as thin or linen sacks woven together in the form of webs [32, 33]. These nets do not change the natural composition of light; only the light spectrum passing through the net is changed. The benefits of using net shading on plants in drought stress conditions are improving plant water status and yield, delaying fruit maturation to ripen more fruit, and reducing photo-inhibition. In severe water stress conditions, net shade is effective in the long term [34, 35]. Net shading may also harm fruit growth capacity because it reduces the amount of light received by the plant.

Nevertheless, single or multi-layer shades with different light transmission percentages is used [31]. An example of polyethylene shade with layers and different light transmission percentages is presented in **Figure 4**. As mentioned in **Figure 4**, shading was carried out with commercial green and reticular polyethylene shade, which transmits about 70, 50, and 0% of incident light from left to right, respectively.

Other drought stress management methods include exogenous application of plant growth regulators (PGRs), such as abscisic acid (ABA), auxin, gibberellic acid, brassinolide, jasmonates, benzyl-adenine, salicylic acid (SA), and biostimulants. PGRs are nonnutritive organic compounds that control different phases of plant growth and development as secondary stress messengers and play an essential role in reducing these abiotic stress conditions. For example, a study on citrus has shown that jasmonic acid (JA) signaling pathways are effective in water stress. In citrumelo CPB 4475 (*Citrus paradisi* × *Poncirus trifoliate*), a hybrid citrus genotype used as a rootstock, it was found that the exogenous JA application can also effectively diminish the damage caused by drought to plants [37]. Also, rootstock breeding and biotechnological approaches can mitigate climate change effects and increase drought tolerance in citrus [33, 38].

2.2 Extreme temperature stress and its management and mitigation strategies

Climate change has caused severe problems, especially global warming, which has increased the earth's average temperature by four degrees fahrenheit compared to the ice age. **Figure 5** shows the increase in the earth's temperature from 1884 to

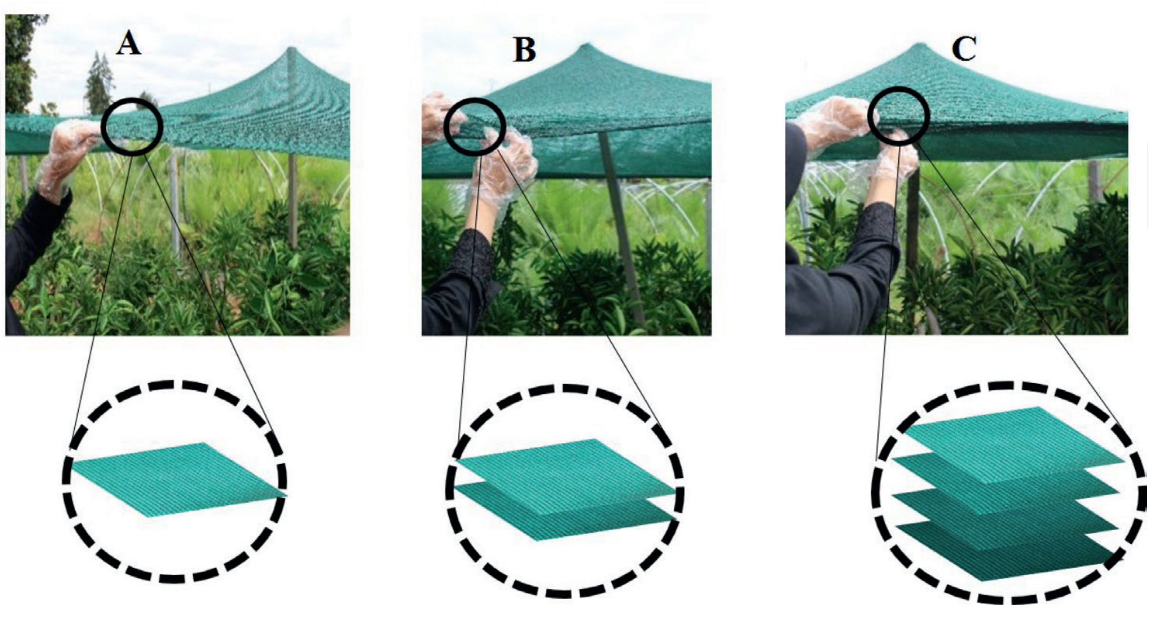

Figure 4.
Green and reticular polyethylene shades with one (A), two (B), and four (C) layers on page mandarin seedlings, from left to right, respectively [36].

2021. Climate change and agriculture are interrelated activities and affect citrus as one of the largest fruit crops in the world. The growth and yield of citrus begin to change when the environmental temperature increases; the water required by the plant decreases [39]. Extreme temperature causes biochemical, morphological, physiological, and genetic changes in citrus. High temperatures in citrus growing regions can lead to significant leaf-to-air vapor pressure difference (D) and excessive leaf temperature in sun-exposed leaves. This high-temperature stress can diminish net CO_2 assimilation, growth, fruit yield, and citrus quality. The critical stages of citrus phenology increase the abscission of reproductive structures and the dropping of young fruit [40]. In citrus, high temperatures cause the generation of reactive oxygen species (ROS), the decline in chlorophyll content, an accumulation of carotenoids, and delayed coloration [41]. Research conducted on Carrizo citrange and Cleopatra mandarin showed that heat increases the phenolic compounds, the composition of secondary metabolites, and the antioxidant capacity of the leaves [42].

The plant's nutritional requirements are higher during the flowering and fruiting of citrus, and trees produce and accumulate the most carbohydrates during the growth stage. Citrus trees have a lot of nutritional requirements during the flowering and fruiting period; therefore, in the growth stage, trees produce and accumulate carbohydrates more than other materials. If nutrient accumulation is insufficient, high temperature may lead to increased respiration and diminishing photosynthesis, which causes nutritional imbalance and thus exacerbates flower and fruit drops [43]. The high temperature increased the fruit drops of Nagami Kumquat [43] and Tosa Buntan pummelo (*Citrus grandis* (L.) Osbeck) trees [44].

Global warming, and, as a result, extreme temperature stress is a dangerous challenge for agricultural products, including citrus fruits, and requires efficient strategies to ensure the production of quality products. One of the effective strategies is kaolin particle film application (**Figure 6**). The kaolin application is a suitable strategy to deal with the increasing temperature of the environment caused by global warming. It can also significantly help to expand the growth of citrus fruits in areas

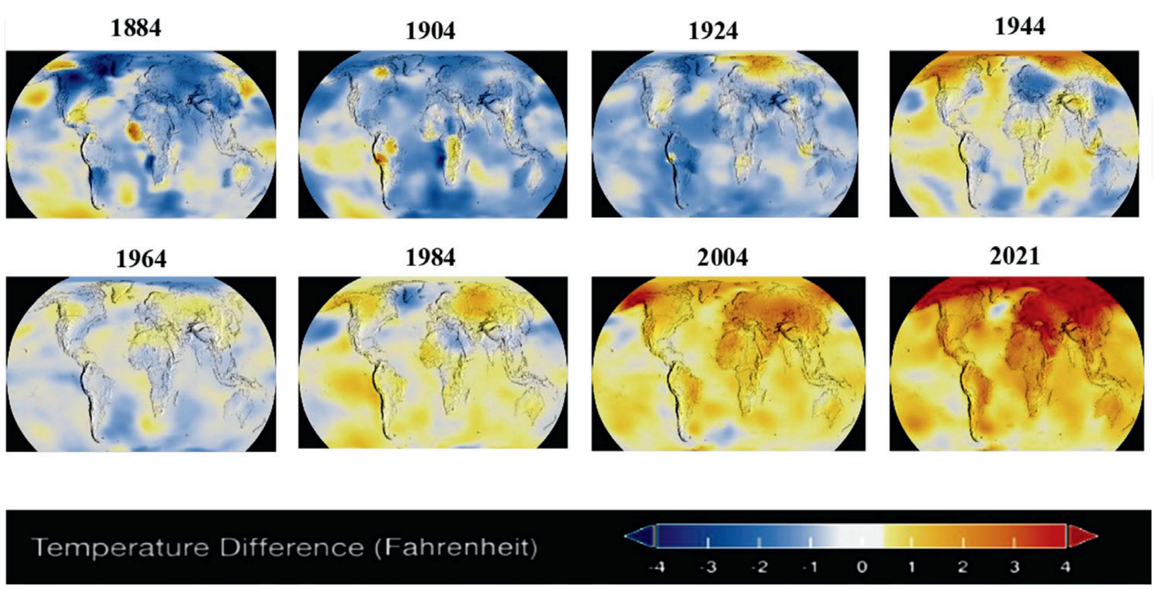

Figure 5.
Global temperature changes from 1884 to 2021 (adapted from NASA/GISS).

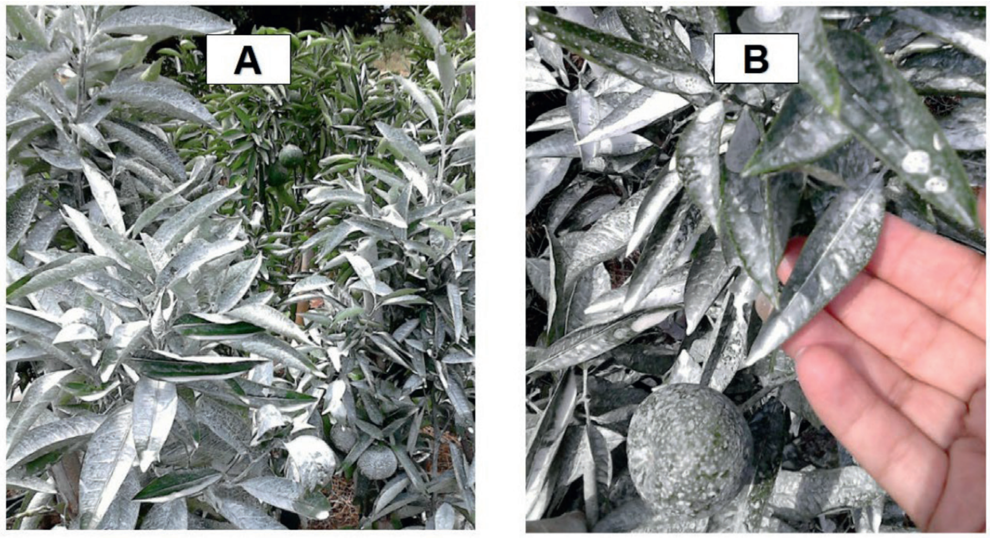

Figure 6.
Kaolin clay particles application on page mandarin (Citrus reticulata) trees. The page mandarin trees were treated with 7% (A) and 5% (B) kaolin clay [36].

that suffer from summer heat stress. The main effect of kaolin is to increase solar radiation reflection and reduce, consequently, the temperature of the leaves exposed to light in the hottest hours [29, 34]. By reflecting a part of the light irradiated to the plant, kaolin significantly reduces the temperature of the leaves. It also prevents the accumulation of Pro by increasing the potential and maintaining the relative water content of the leaves in the summer. As a result, it reduces the adverse effects of drought stress. The effects of lowering temperature are reducing water consumption, increasing chlorophyll content, maintaining the quantitative and qualitative characteristics of the product, and preventing bursting and sunburn of citrus fruit, which was found in research conducted on Balady mandarin (*Citrus reticulata* Blanco) [29] and grapefruit [28] have been evident. **Figure 6** shows page mandarin (*C. reticulata*) trees sprayed with kaolin.

In citrus-producing regions, net shading could ameliorate leaf water use efficiency, photosynthesis, and fruit quality, especially in citrus seedlings, where most leaves are exposed to sunlight. The advantages of using these shades include reducing sunlight radiation intensity, especially in hot seasons, soil water maintenance, reducing wind speed, reducing leaf temperature, and photo-inhibition [32, 45]. Growth improvement, increasing fruit yield and quality and net gas exchange, mitigating fruit dropping, and other advantages, such as protecting the plant against bird attacks, insects, rain, and high daily, and night temperatures [46]. Compost application can also reduce soil temperature, allowing better root growth and ultimately decomposition and adding significant organic matter to the soil [30, 47]. Some research were carried out on the effect of methyl jasmonate (MeJA) on citrus under high-temperature stress. Findings found that the JA, and JA-isoleucine accumulation, were induced in heat stress conditions, which can further counteract the harmful effects of extreme temperature stress by closing the stomata and reducing transpiration [21, 48, 49]. In addition, in citrus-growing regions, high temperatures will increase irrigation requirements. Therefore, the pressure on the underground aquifers increases the soil salinity. All these stress factors have undesirable results in citrus cultivation.

2.3 Soil salinity and sodicity stress and its management and mitigation strategies

Soil salinity and sodicity are abiotic stresses that prevent the growth of trees, especially citrus, by limiting water and mineral uptake. Citrus is one of the salt-sensitive and salt-intolerant crops, and their response to soil salinity and sodicity depends on rootstock, scion, soil type, irrigation system, and climate. Changing these factors, under the same irrigation conditions, could generate entirely different results. Salinity reduces growth in citrus trees and causes physiological disorders [50]. Salinity damage happens when the dissolved salt in water is high enough to diminish crop growth. Indirect movement of water in the leaf tissues of citrus can cause accumulation of Cl^- ions affecting transpiration and photosynthesis, and increasing Cl − ions concentrations, accelerates defoliation by enhancing leaf abscission and ethylene production [51]. The most common causes of soil salinity and sodicity are hydrological, geological, and soil processes. Other reasons are incompetent irrigation methods, improper drainage systems, dry weather or insufficient annual rainfall, and remaining salts accumulated in plant root areas [52].

The effect of soil salinity on the citrus growth parameters may be seen as decreased plant height, leaf area, stem diameter, fresh and dry weight, and increased tree senescence [50]. The decrease in growth indices may also be due to the salt osmotic effect on the roots and the toxic ions accumulated in plant organs. The addition of sodium chloride (NaCl) in growth media increments phosphorus, nitrogen, and potassium and alleviates calcium and magnesium in most citrus rootstocks [53]. Citrus physiological responses to salt stress might be attributed to changes in water relations. Citrus species, such as halophyte plants, cannot absorb salts from the soil solution and accumulate them in their tissues to regulate osmotic pressure. Instead, they accumulate secondary metabolites, such as pro and nontoxic inorganic ions, in their cells to overcome salinity stress. Salt accumulation in chloroplasts reduces chlorophyll content and directly affects and reduces photosynthetic activities and yield [50, 54].

Phytophthora root rot in citrus fruit is usually intensified under salinity stress conditions. Also, a reduction in number, weight, and fruit yield is observed in citrus fruit under salt stress. Salinity decreases plant growth and yield and reduces shoot and root biomass [55]. The plant pigment contents decrease in response to salt stress due to CL accumulation, destruction of chlorophyll biosynthesis, and the reduction in iron, magnesium, and manganese in several citrus rootstocks [56]. Reduced chlorophyll content in citrus rootstocks due to NaCl application was also reported [57, 58]. The figure below shows the adverse effects of salinity stress on the nutritional, physiological, and biochemical characteristics of four citrus species (**Figure 7**).

Since citrus fruits are one of the most sensitive plants, salinity stress reduces fruit yield and quality. So, improvement programs should be considered for better productivity of citrus fruits in soils affected by salt. One of the methods of managing salinity stress in citrus fruits is irrigation programming. Irrigation is an essential factor in managing salinity in areas with salinity stress. Increasing irrigation periodicity is recommended to leach the salts and minimize the salt concentration in the root zone [57]. Leaf and trunk damage related to the absorption of salt can be reduced by using micro-irrigation systems. Another strategy to diminish salinity stress is recommended repetitious fertilization or spreading dry fertilizers through fertigation. It is necessary to mention that nutrient fertilizers should not contain chloride (CL) or sodium (Na). In areas where the soil is sodium, calcium source application (gypsum; $CaSO_4$)

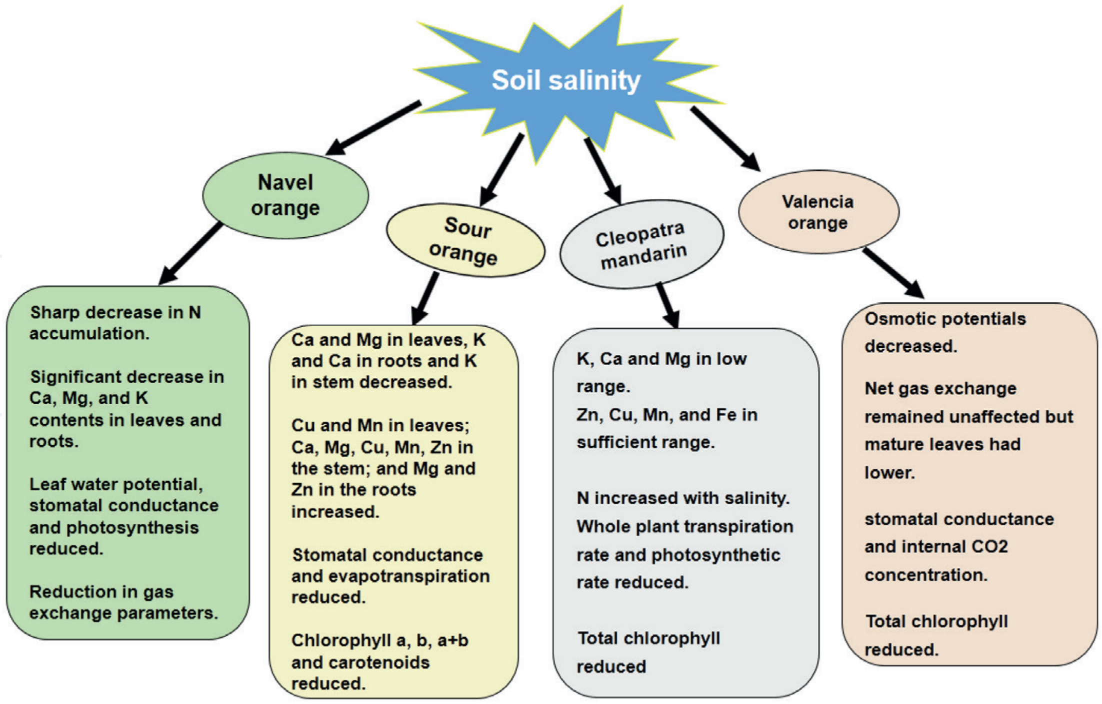

Figure 7.
Effect of soil salinity on nutritional, physiological, and biochemical parameters in four citrus species [59–61].

reduces the adverse effect of sodium on shoot growth and improves plant growth in these conditions [50, 62].

Plant breeding and genetic manipulations are other ways of managing salinity and sodicity stress conditions, which increase the plant's adaptation to saline environments and salt tolerance. Currently, inorganic and organic conditioners like organic residues, phosphor-gypsum, and H_2SO_4, calcium application, drainage management, the genetic use of halophytic traits, arbuscular mycorrhizal, and avoiding cultivation of lands with high groundwater are being used to progress citrus productivities in salt-affected soils [62–65]. Quantitative trait locus (*QTL*) mapping is one way to identify salinity tolerance genes. This way has focused on characterizing genes encoding proteins involved in decreasing the amount of Na^+ from the root to the shoot [66].

Since drought stress is the beginning of creating salinity stress in the soils of dry and salty areas, therefore, methods, such as the use of superabsorbent, netting shades, the application of phytohormones, such as abscisic acid (ABA), polyamines, and chemical priming, will improve the performance of citrus fruits under salinity stress condition [34]. The application of nitrate and other compounds derived from nitrogen (urea or ammonium) has positively affected citrus morpho-physiological and biochemical responses under salt stress conditions [67]. Nitrate appears to stimulate photosynthesis and growth parameters as well as reduce leaf drop. Also, the increased nitrogen in leaf biomass leads to chloride dilution [68]. The beneficial effect of Paclobutrazol (PBZ) under salinity on the accumulation of photosynthetic pigments, phytohormones, and root morphology, such as size, number of lateral roots, and dry weight of roots, has also been documented [69].

2.4 Cold stress and its management and mitigation strategies

Low temperature is the main restrictive factor for citrus growth and productivity worldwide. Citrus is grown at temperatures between 12.8 and 38°C; low temperatures below 13°C limit vegetative growth and fruit growth and delay maturity. The threshold temperature that destroys shoots is −12°C, but some citrus fruit can tolerate a temperature of −10°C [70]. *Poncirus trifoliata* (L.) Raf. is the most tolerant citrus rootstock to low temperatures [71]. The low ambient temperature that causes cold stress is a principal environmental abiotic stress. In these conditions, the production of reactive oxygen species (ROS), such as superoxide radicals, hydrogen peroxide, hydroxyl, and singlet oxygen is increased, which leads to ion leakage and water soaking **Figure 8**, and finally, leaves are destroyed. ROS produced in the chloroplast can destroy cellular components, such as proteins, pigments, membranes, lipids, and nucleic acids [39, 73].

Additionally, mechanical methods can decrease these damages to increase plant resistance against cold and frost damage. One of the strategies is the osmotic balance reaction to maintain plant water content. These activities are affected by osmotic pressure regulatory concentration compounds, such as secondary metabolites, including proline, and some inorganic ions, such as potassium. Potassium increases cells' tolerance against cold stress because it affects the freezing point of the liquid inside the vacuoles [74]. High potassium levels protected cells against freezing by lowering the freezing point of the cell solution [75]. Potassium can affect plant survival under different environmental stresses by creating osmotic balance and protection against oxidative damage. Potassium causes leakage and maintenance of water in plant tissues with increasing osmotic pressure and cell membrane fluidity; thus, it prevents cell membrane rupture and plant tissue damage and increases electrolyte leakage [76].

Potassium substantially affects stomata movement and water relation (turgor regulation and osmotic adjustment) in plants under cold conditions. The present results agree with those reported on Sour orange (*C. aurantium* L.) seedlings [77]. Numerous studies indicated that applying abscisic acid (ABA) may increase leaf water content under low-temperature stress [78]. The grafting technique and the use of tolerant rootstocks to cold stresses allow farmers to protect crops against various abiotic stresses, especially cold stress. A study in common clementine with a tetraploid Carrizo Citrange rootstock showed enhanced natural chilling stress tolerance [79].

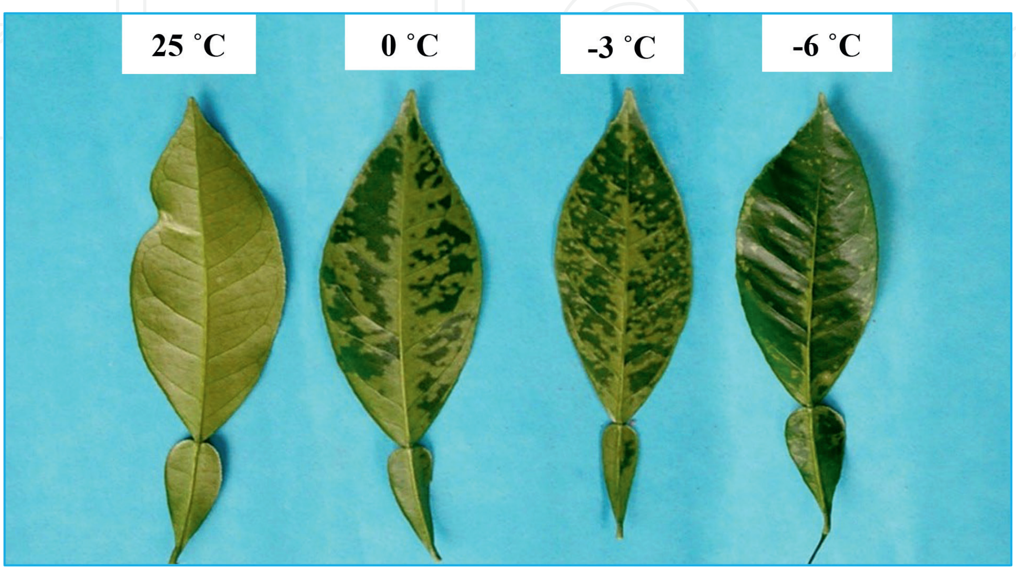

Figure 8.
Damaged leaves of sour orange (Citrus aurantium L.) seedlings were exposed to 0, −3, and − 6°C for 24 hours [72].

3. Conclusions

Citrus species is the world's most productive and widely consumed horticultural crops. The factors limiting citrus growth in tropical and subtropical climates are significantly different. Due to abiotic stresses, such as drought, salinity, and high and low temperature, citrus production confronts risks. For this reason, it is crucial using strategies to manage these stresses. Drought and extreme temperatures caused heavy fruit drops and a decline in yield, and it also increases the cracking and folding of fruit and reduces the product yield. Therefore, measures to prevent these problems should be taken in case of severe drought and high temperatures. To manage drought stress and high temperature, using superabsorbents, kaolin, and pure shade is less expensive than producing the product. Also, drought stress management and high-temperature in hot and dry areas reduce the possibility of salinity stress.

Kaolin particle film and shading net reduce water loss through the increasing reflectance of ultraviolet and infrared radiations, thereby reducing leaves and fruit tissue temperature. Kaolin application could be considered an implement to be used in tropical regions to improve plant acclimation to extreme temperatures and high radiation levels in citrus. Maintaining soil moisture, reducing water consumption, and taking advantage of suitable yield along with relative improvement of fruit quality of growth and fruiting period of citrus is essential. For this purpose, soil amendment with superabsorbent polymers to provide moisture in the root area and increase available water in water shortage conditions improve some physiological, biochemical, and phytochemical properties of citrus. Also, the uniformity of humidity during the plant growth period with the use of superabsorbent plays a role of importance in reducing other indicators, such as fruit bursting. Therefore, it is recommended to use this superabsorbent polymer in areas that face water shortages and improper distribution of precipitation. Exogenous application of phytohormones and hormones and even suitable nutrition of citrus fruits can also increase plant tolerance against abiotic stresses. Among the methods that can protect the plant from low-temperature stress are grafting techniques, plant breeding programs, osmotic balance reactions to maintain plant water content secondary metabolites, proline, and inorganic ions, such as potassium.

Citrus is salt-sensitive, and soil salinity reduces citrus growth and causes physiological disorders. Salt stress lowers stomatal conductance, net CO_2 assimilation, and water potential of citrus leaves. Additionally, it causes an excessive concentration of sodium or chloride in citrus leaves. Increasing irrigation periodicity, fertilization and fertigation, Plant breeding, and genetic manipulations are among the methods of managing salinity stress in citrus fruits. In the presence of an adequate concentration of calcium in saline irrigation water, calcium improved the effects of saline on the plant's growth. Therefore, the plants could tolerate the effects of high salinity concentration. The authors' practical experience has shown that abiotic stresses occur worldwide in almost all citrus-growing areas. This research has attempted to explain citrus fruit management and improvement strategies to withstand abiotic stresses in citrus fruit production.

Conflict of interest

The authors have no conflict of interest with any person or institution.

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