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Citriculture in the Face of Climate Change

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ABSTRACT: Climate change is a threat to citriculture and the need to analyze the potential effects of further change in the climate by studying the current state cannot be overemphasized. It is necessary in order to ensure continued successful production of citrus and other horticultural crops in the predictable scenario. The continuously rising temperature and other adverse climate phenomena are altering the environmental conditions in the regions where citrus varieties are currently being cultivated. These fluctuations in the environment that can arise because of rising temperature like water stress in terms of drought and flood or salinity jeopardize the citrus physiology, growth and production and in extreme cases, even plant survival. Studying the plant responses to climate change may hold the key to minimizing the changes while maintaining the production and productivity.

Keywords: Citrus, citriculture, climate change, effects.

I. INTRODUCTION

There are over 30 countries in the world where citrus is commercially grown. In general, the production of this product is concentrated in the regions between 40° N and S, where the base minimum temperature is generally above 20°F. Different climatic zones exist at these latitudes which have a profound effect on citrus growth, development, yield, and quality. It is becoming increasingly clear that climate change is on the rise, and we are only just beginning to see the tip of the iceberg at this point in time. We cannot even begin to imagine how it will affect citriculture around the world in the future. As a result of climate change, increased temperatures have been reported, longer durations of moisture stress have been reported, pest and disease incidence has increased, salinity levels have been elevated, and floods have been reported [1]. It is a challenge to counteract its impact on the growth, development, quality and yield of the global citrus production. We will be glazing through the consequences of climate change on the production and productivity of citrus in the upcoming aspects.

Farmer's perception of climate change and its effects. A study of farmers' knowledge of climate change and their level of production is necessary during this period of climate change. It is not uncommon for farmers to be unfamiliar with the concept of climate change, so let us take a closer look at how citrus growers perceive it. A participatory survey was conducted among 65 citrus producers in Campeche, Mexico by Martinez *et al.* [2]. In this survey, the objective was to assess the perceptions of citrus growers regarding the effects of climate change. The study found that 66.6% of the participants were aware of climate change, with television being the primary source of information. In response to the issue at hand, 69.6% of farmers modified their cultivation pattern such as the type of tillage. A lack of technical irrigation systems has resulted in low citrus fruits production due to climate change, specifically the temperature increase and the reduction in precipitation. There were, however, no quantifications or assessments of the damages caused by this phenomenon, nor were strategies developed to counteract its current and long-term effects.

Similarly, Adebisi-Adelani and Akeredolu conducted a study in Nigeria in 2020. Using the Multistage Sampling technique, 441 tomato and citrus farmers were interviewed using Focus Group Discussions (FGDs), a structured interview schedule, and secondary data from FAOSTAT [3]. The results of this study indicate that there is no significant connection between respondents' awareness of climate change and changes in the production of both crops. In this case, it is unlikely that the amount of knowledge one has on climate change affects production, whereas adaption strategies are crucial. Citrus and tomato farmers have adopted adaptation strategies against climate change that include moving crop planting dates, using varieties resistant to pests and diseases, and adjusting the timing and location of cropping activities.

Effect on Water requirement and Irrigation. In order to reach an economic crop level, citrus plants generally receive moderate water stress for 60 to 70 days. Conversely, extreme drought would limit tree productivity and require irrigation to produce crops. It is possible to exhaust underground or river water for irrigation purposes when rainfall is insufficient for the crop's optimum growth and development. In addition to global warming and increased ocean temperatures, the frequency of harsher hurricanes can also increase as a result of global warming. Consequently, fruit will be lost and trees will be injured in an unacceptable way [4].

Insufficient water coupled with an increase in temperature adversely affects photosynthesis and increases oxidative damage. Citrus cultivation is adversely affected when multiple environmental stresses occur simultaneously [5].

Using the citrus irrigation requirements (IRR) in major global citrus producing areas of Africa, Asia, Australia, Mediterranean, and Americas, an investigation was conducted to understand how future climate change will impact water resources for citrus production in the future. The Irrigation Management System (IManSys) model was used to compute the optimum IRR for a baseline period (1986–2005) and two future periods (2055s and 2090s). In the future, annual IRRs were predicted to decrease worldwide, while monthly IRRs varied. CO2 concentration increases result in a 37% and 12% decrease in IRR and evapotranspiration, respectively. Inverse correlation exists between yearly rainfall projections and changes in IRR. It is predicted that drainage below citrus root zones and citrus canopy interception will increase marginally in the future. Based on the projections of this study, we can better understand how climate change might affect citrus IRRs and water budgets [6].

Similarly, a study was conducted in Egypt to analyze how climate change might affect citrus and olive irrigation requirement (IR) and water productivity (WP). Based on projections of the future climate taken from the HaCM3 global climate model, the study was conducted in El-Bihera, Al-Dakahlia, Matruh and North of Sinai governorates of Egypt using a CROPWAT 8.0 model. For citrus and olive, the IRs increased by 21.80% and 27.51% in each of the future periods (2020s, 2050s, and 2100s) compared to the current period (1990-2019). As compared to the current period (1990-2019), citrus and olive WP values decreased by 43.21% and 17.99% for all future periods (2020s, 2050s, 2100s). Under climate change scenarios in Egypt, this study can provide useful projections for identifying adaptation measures to address water stress and increase yield of citrus and olive crops [7].

Desalinated seawater (DSW) is a popular alternative source of irrigation for arid and semi-arid regions due to a lack of natural water resources. Citrus species are notoriously salt- and boron-sensitive so DSWs can compromise crop productivity; in this case, rootstocks can strengthen the tree's tolerance to abiotic stresses. *Citrus macrophylla* (CM) and sour orange (SO) rootstocks were used in Navarro *et al.* [8] study, where SO is more salinity and boron tolerant than CM. As part of the experiment, three types of water were irrigated: DSW, DLB (DSW with low boron) and distilled water (Control) supplemented with Hoagland nutrients. Seven months after irrigation, the crop was harvested. The rootstocks greatly dictated the response to high levels of Cl^-, Na^+ and B. Even under the high temperature, the growth of plants grafted on SO was not affected by DSW and also did not reach the Cl^- threshold of phytotoxicity, so the decrease in the shoot growth of plants grafted on CM due to DSW irrigation was related more to Cl^- rather than the foliar Na^+ accumulation. As a result of grafting on SO and irrigating with DSW, plants grafted on CM accumulated more B, exceeding the phytotoxicity threshold and exerting greater oxidative stress than those grafted on SO and irrigated with DSW. The growth rate of these plants was not affected by DSW, so the concentration of B has no direct relationship to the growth rate of these plants. DSW at high temperatures could be used to irrigate citrus crops if ever needed, since citrus plants' response to DSW is dependent on their rootstock, thereby causing the scarcity of water in citrus-growing regions to be exacerbated.

Impact on growth and productivity. Temperature, humidity, light intensity, and solar radiation are some of citrus' specific climatic requirements. Drought and temperature stress negatively affect yield and fruit quality. As a result of climatic conditions, pests, diseases, and weeds are more likely to spread and hinder the plant's growth. Citrus were generally considered to grow best in a Mediterranean climate, but due to global warming and constant climate changes, there is a change in the growth behavior of the tree, resulting in the need to regulate cultivation practices within the growing season and alter the growing season itself. It has been demonstrated that citrus cultivation is negatively affected by erratic climate conditions due to erratic conditions, including extreme temperature changes, heat waves, flooding, drought, soil salinity, but the two biggest threats are rising temperatures and droughts [5].

Albrigo [4] predicted that the floral bud formation induced by lower temperatures would be adversely affected if the average temperatures were to increase by 2°C and the years with sufficient cool temperature accumulation for flower bud induction would decrease in the Caribbean Basin. In the meantime, it is not possible to predict how drought stress would occur in winter or whether drought periods would shift throughout the year.

Assessment of the effect of climatic varietes on fruit-bearing mechanism was conducted in the Kinnow growing regions of Pakistan viz. Sargodha, Toba Tek Singh (TTS) and Vehari districts. These three areas are located in different agro-ecological zones. In warmer climates, fluctuations in temperature influence not only phenology, but also fruiting patterns, fruit droppings, and therefore yield and quality characteristics. Due to erratic weather patterns in TTS and Vehari, the plants were alternating bearing patterns, which disrupted the source-sink relationship, resulting in declining fruit quality and affecting the plant's thermal use efficiency. More climate-variable regions exhibited a biannual fruiting pattern. Kinnow Mandarin's fruiting habit, yield, and quality attributes are determined by environmental factors [9].

Effects on fruit quality and development. According to Collins *et al.* [10], environmental factors influence the quality of citrus fruits. Even after citrus fruit has been harvested, the quality of the fruit is affected [11]. Citrus fruit skins exposed to excessive light and heat develop Sunscald, resulting in their discoloration [12]. The temperature difference between the fruit surface and the patches with higher temperatures can lead to uneven ripening. Different quality and storability of fruit within and between orchards can also cause uneven ripening. It can be detrimental to get sunburn if the temperature rises above 40 °C. As well as the outside of the fruit, the inside may be damaged, which would affect its quality. A second consequence could be the drying of segments as a result of the granulation of gel inside of the vesicles. The intensity of granulation has been found to be increased by hot, dry conditions at flowering. The stems and leaves of a tree can be injured by other atrocities such as hail, which can be quite destructive to fruit and tree as a whole. In turn, these injured trees are more likely to be infected, which invites mold and fungi to thrive there. As citrus trees are native to tropical and subtropical regions, they are sensitive to cold and low temperatures, therefore they can be vulnerable to frost and other climate-related problems. Therefore, trees can be negatively affected by temperatures near and above freezing. Erena *et al.* [13] assessed the natural degreening of lemons fruits under the influence of potential climate change taking three climatic scenarios into consideration. In early autumn, the temperature drops, causing the yellow colour to form, which means chlorophyll begins to breakdown. It was found that, in different climatic models, the onset of fruit color development will be delayed by one to two months due to an increase in air temperature. All three scenarios will result in the fruits not attaining their characteristic color on the tree, so degreening chambers will be required, which will increase production costs.

Effect on pests and pathogens. Donkersley *et al.* [14] reported that the rising global temperatures as a result of climate change will affect the distribution and breeding behaviour of pests and pathogens prevalent in citrus crops. When citrus is grown at warmer temperatures, the population of *Candidatus Liberibacter asiaticus* surges and *Diaphorina citri* acquisition rates decline, indicates that the incidence and spread of pathogens are heavily affected by ambient temperatures. Phenological shifts may also intensify the threats posed by meteorological elements like storms and frosts. The incidence of diseases may also be more prevalent due to the climatic fluctuations. Martinez-Minaya *et al.* [2] reported that the natural spread of citrus black spot (CBS) disease caused by *Phyllosticta citricarpa*, has greatly been affected and has expanded its original geographical range from summer rainfall to drier regions over the last decades due to the rainfall distribution in South Africa.

Effect of elevated atmospheric CO_2. An analysis of the response of citrus genotypes, *viz.* Citrumelo, citrange, sweet oranges, and sour oranges are all also responsive to elevated CO_2 levels. A comparison of fourteen-week-old Carrizo Citrange and Swingle Citrumelo seedlings grown under double-ambient CO_2 for five months revealed that there were 69 to 94% more new shoots, an increase in total shoot dry weight of over 100%, an increase in total root dry weight of 37 to 100%, an increase in total leaf area of 85 to 124%, and an increase in total dry matter accumulation of 111 to 115%. Another experiment, in which nine-week-old Carrizo citrange seedlings were placed under double- and triple-ambient [CO_2] conditions for 17 weeks, showed dry matter increases of 67 and 120%, respectively [15].

The effects of atmospheric CO_2 on the growth and fruit production of sour orange trees were studied by Idso *et al.* [16] in Phoenix, Arizona. Seedlings of sour orange were grown outdoors in clear-plastic wall and open-top structures. Half of them were grown at near-ambient CO_2 (400 ppm), the other half at 300 ppm above ambient (CO_2-enriched). The results of this study revealed that citrus species responded more strongly to rising atmospheric CO_2.

The yield response of 3-year-old Valencia sweet orange trees was studied by Downton *et al.* [17]. CO_2 concentrations of 400 ppm were used as the control, while 800 ppm was used as the enrichment. The fruit size and weight of enriched (800 ppm) trees are similar to those of control trees during the same period. A future increase in CO_2 and temperature will likely cause genotype-specific variations in the photosynthetic rate of citrus due to differences in growth and yield responses to elevated growth [CO_2]. CO_2 enrichment has also been reported to have influenced citrus growth and yield in a variety of ways, depending on the growing environment, levels, and durations of the CO_2 treatment.

Impact on the economy of citrus fruit production. Ahmad *et al.* [18] assessed the economic impact of climate change on the citrus fruit production in Punjab using annual data from 1989 to 2015 to assess the effect of climate change on the citrus fruit production in Pakistan. Based on the Auto Regressive Distributed Lag (ARDL) model, the study was conducted. The results indicated that temperature and rainfall had a direct impact on citrus fruit production and profitability. The results of this study confirmed that climate change had a negative impact on production. Citrus fruit production is negatively impacted by climate elements such as temperature and rainfall. Citrus production and climate change have a long-standing relationship.

Effect on Supply Response. It was observed that fresh orange acreage and grapefruit yield responses for the state of Florida, USA, responded positively to climate change under the econometric analysis carried out by Traboulsi [19] using state level data from 1980 to 2010. Grapefruit yield shows a negative response to temperature, whereas orange acreage shows a positive response to temperature. Increasing temperatures will lead to an increase in fresh orange acreage, according to this research. For fresh oranges and grapefruits, it provides a long-term as well as a short-term estimation of the relationship between acreage and yield. Moreover, it demonstrates how temperature can play a role in production shifts as a result of climate change.

Adaptation Strategies for Climate Change. Using semi-structured questionnaires, Joseph *et al.* [20] collected data to check how the adoption of climate change adaptation strategies actually impacted the citrus farmers' production in five Limpopo district municipalities. Farmers have adapted to climate change by harvesting water, planting drought-resistant varieties, and using integrated pest management techniques. Farmers are using fertilizer and water efficiently based on variables such as fertilizer and water cost. The farmers, however, incurred more costs and incurred lower profits when using fertilizers with higher nitrogen contents. A more water-conscious approach should be adopted so that farmers are able to access water more readily. Hence, citrus farmers are still able to adapt to climate change and remain profitable.

Agro-forestry can also help farmers diversify their incomes and combat climate change. Using citrus-based intercropping systems in six sites of Sargodha district, Southeast Pakistan, Yasin *et al.* [21] investigated above- and below-ground biomass and soil carbon. Across study areas, the total carbon stocks differed due to differences in citrus tree age and growth pattern, as well as their management. In addition to storing carbon in the soil, the citrus-based system stored carbon in tree biomass. By capturing CO_2 from the atmosphere, fruit-based agroforestry planting systems can contribute to combating climate change. Moreover, local dwellers in underdeveloped countries can benefit from agro-forestry by ensuring livelihood security. By utilizing agro-forestry systems, farmers can address environment issues while increasing their incomes.

CONCLUSION

Citrus and horticultural crops have been affected by climate change, so adaptation strategies that can counteract the effect of climate change need to be explored. On a global scale, agricultural production has increasingly become dependent on adaptation policies and strategies. It is necessary to implement different strategies for climate change adaptation in tropical regions because the region already experiences a hot and dry climate. In light of its mechanism of action, it may be utilized in preventing further damage to citrus plants.

Conflict of interest. None.

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