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Review Article

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The Effects of Climate Change on the Future of Citrus Growth in the Mediterranean Region Change

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ABSTRACT
Citrus fruit production is one of the largest fruit crop productions in the World, especially in the Mediterranean area. The future of citrus plantations in the sub-tropical region depends on climate change. Eight billion world's population's activity and energy demand is getting increased and as a result, more greenhouse gases are fluxing into the atmosphere. All the atmospheric data such as CO_2 and other gases concentrations are increasing and weather patterns are continuously changing which results in climate change. Agricultural productivity and climate change parameters are interrelated in many ways. Abiotic stresses such as temperature and water stress are the main environmental factors that reduce yield at a drastic level. Climate-based stress factors cause physiological, biochemical, and anatomical changes in plant growth and structure. Stress factors also lead to a reduction in crop yield. An increase in temperature and water deficiency is expected to result in reduced citrus tree fruit growth and in turn decreased yield. In the present work, the effects of greenhouse gases on climate change and the citrus plantation future are discussed. Since net carbon dioxide assimilation in plant leaves and stomatal conductance is reduced by high leaf temperature, plant growth is depressed. Due to water deficiency, the transpiration rate and stomatal conductance are naturally reduced, and in turn, the yield will be reduced. Knowing the possible effects of climate change on photosynthesis productivity and CO_2 assimilation capacity in citrus plants is better. In addition, it is better to know what can be done to keep yield at optimum levels. Also, it is better to know the rhizosphere organism's role in the mitigation of greenhouse gases to reduce climate change effects on agricultural sustainability.
Keywords: Citrus plant and citrus fruits yield, Global warming, Abiotic stress factors, Climatic adaptation factors.

INTRODUCTION

The CO_2 Concentration in The Atmosphere Is Increasing

The main factors accelerating climate changes are surface released greenhouse gases methane, nitric oxide, especially CO_2 gas to the atmosphere. CO_2 gas is shaped as results of organic carbon-based materials oxidation. Climate change is accelerated by human activities such as using fossil fuel, heavy tillage, using high fertilizer and other chemicals etc.

Atmospheric CO_2 concentrations have significant effects on climate change and consequently have effects on the sustainability of ecosystem. The factors affecting the CO_2 emission from agricultural practices are crucial for global warming. Since the industrial revolution, the CO_2 concentration in the atmosphere has already changed from 280 to 414 ppm. The increase in annual means on the average growth rate for the past decade (~2.08 ppm yr–1). Not only CO_2, methane and nitrous oxide gases are also increased with time, especially in the last 100 years the increases are significant (Figure 1). As a result of increased greenhouse gases, the atmospheric temperature is also increasing. Earth's average surface temperature is increasing as a result of the greenhouse effect due to the greenhouse gases, such as carbon dioxide emissions from burning fossil fuels and from deforestation and degradation of organic materials. The temperature increase is coordinately caused by several unexpected natural disasters such as drought, heavy and sudden rains, hailstorms and others.

Although the main greenhouse gasses are caused by fossil fuel burning, the agricultural managements also have a great effect on greenhouse gases released to the atmosphere. According to FAO's data, soil and corps management significantly increases atmospheric CO_2 gases quantity within time from 1960 to 2020 (Table 1). In India, in 1961, the atmospheric CO_2 quantity was 502069 billion ton, in year 2020 this was 2082919 billion tons. In the last 60 years, 24 % more CO_2 released into the atmosphere. In the same time, in Turkey, CO_2 released from agricultural soil to the atmosphere in 1960 was 133429 billion tons; in 2020 was 286314 million tons. The increase is 47% more than expected. Other gasses equivalent to CO_2 emission in the agricultural land is increasing for both countries.

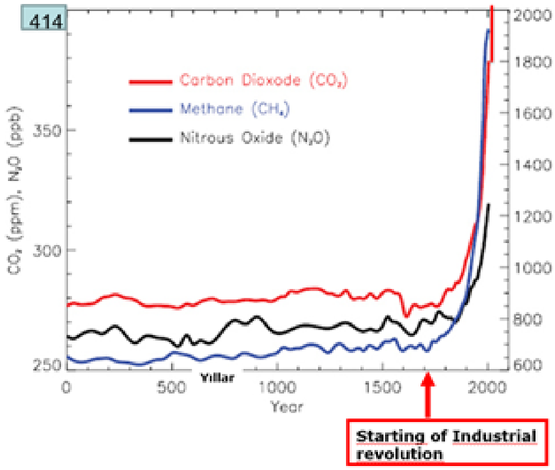

Figure 1. Greenhouse gas flux in to the atmosphere and temperature increase. (*IPCC AR5, 2020)*

As can be seen in Figure 2A, the atmospheric temperature increased from the industrial revolution time to today by decadal land-surface changes determined by several international organization's average temperature measurements. In the last 60 years, from 1990 to 2020, atmospheric temperature increases nearly 1.5 degrees (Figure 2B). Since the human population suddenly increased, the population made significant pressure on land use and energy demand. The main factors causing climate change are energy use which caused the CO_2 release into the atmosphere. According to FAOSTAT, (2023) data from 1961 to 2021 surface temperature increased over 1.7 ^{0}C degrees. United nation (UN), EU and other governmental organizations are trying to keep temperature change less than 1.5 degrees up to end of the century.

Table 1. From 1961 to 2020 Agricultural soil CO_2 and CO_2 eq emissions released of Turkey and India

Years		Turkey	Billion tons
	Agricultural Soils	Emissions on agricultural land	Emissions on agricultural land
	Emissions (CO2eq) (AR5)	Emissions (CO2eq) (AR5)	Emissions (CO2)
1961	133429		
1970	148148		
1980	202656		
1985	18536		
1990	202631	559387	108771
1995	185542	549964	134342
2000	198572	623653	21092
2005	189667	62501	241774
2009	195193	679337	281819
2013	222968	640643	180894
2017	240964	585439	103403
2020	286314	676923	94061

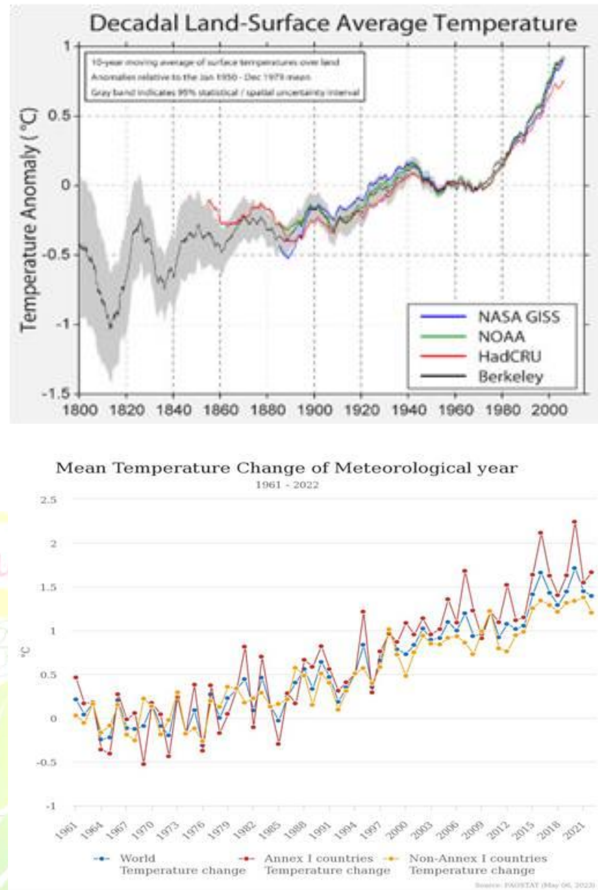

Figure 2. Mean temperature change of meteorological year of world

The Mediterranean Area is Under Climate Change

Soil, water and carbon management are important to supply a suitable medium for citrus growth. There is a frequent rise in water scarcity due to changes in climatic patterns.

It is expected that the world will face a decrease of 66% in water availability by 2050.

Global warming is predicted to cause extreme drought and excessive precipitation in different regions in the future. The Middle East, Asia, and Africa are more exposed to environmental changes due to less preparedness and technology to tackle these issues. There are many nations in North Africa and the Middle East which are at an extremely high risk of water scarcity. The major problems for North Africa to West Asia are water deficiency, low organic matter, erosion, salinization, degradation and desertification which is getting enlarged (Figure 3). Accelerated soil erosion depletes soil fertility and increases emissions of CO_2 and CH_4 from erosion–induced transport of SOC (Lal, 2003). Under arid and semi-arid conditions, soils have low organic matter contents because of high temperatures and decomposition rates.

The future challenges in citrus production under climate change, soil quality and food and water security can be overcome with technology transfer as in the generation of new knowledge.

At present, fertilizer use is more valuable for food production. More yield and cover crops are very important for soil organic carbon pool, soil water content and mitigation of climate change. Increase soil organic matter to keep more water in the soil. Animal manure, compost, biochar and green manure can keep water.

Under expected climate conditions, citrus orchards need to modify the agricultural practices to proper time with physiological processing in the tree. For example, selecting new rootstocks and varieties, using bio stimulants (hormone) and using Arbuscular mycorrhizae inoculated seedlings or use it for soil application could have a significant role in improving citrus vigor and yield crop under improper climate conditions. Biological treatments against new pests and diseases, irrigation and nutrient management can protect plant growth and production.

To reduce the impact of CO_2 on climate change, biodiversity, plant development and environmental enhancement must be combined.

Climate change has great negative impact on biodiversity. The reverse is true as well. Climate change and biodiversity degradation affect each other's negative development. Other forms of degradation also generally release CO_2 into the atmosphere such as deforestation, overgrazing – by stripping the land of vegetation – and wildfires.

In many regions and countries, drylands are already affected by desertification. Only in Southern, Central and Eastern Europe about 25% of land is at high or very high risk of desertification. More than 1/3 of the Mediterranean soils under climate change are under desertification (Figure 4).

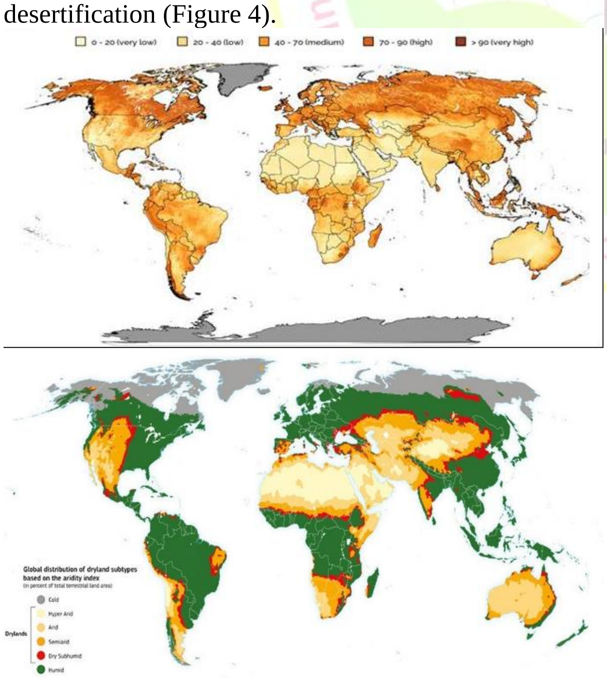

Figure 3. World soil organic carbon content in 2019, ton/ha

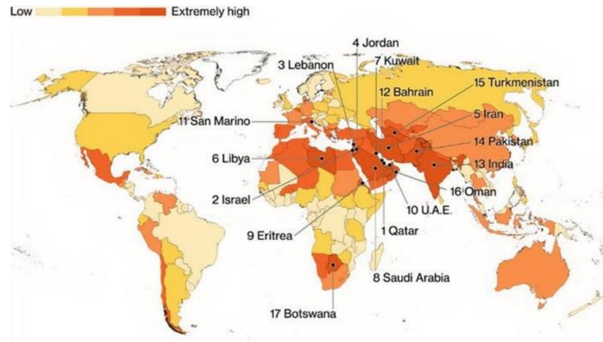

Figure 4. Top 17 countries facing the risk of extremely high-water stress (Hofste et al. 2019).

Figure 5. Citrus Agricultural related to abiotic stress factors (Balfagón et al, 2019)

The Main Abiotic Stressors in Citrus Cultivation

The stress factors directly affecting citrus production are caused by climate change.

Natural and human-caused climate changes created stress factors (Figure 5) such as;

- High temperature
-High radiation
-Deforestation
-Drought
- Salinity
- Flood or water table, which significantly reduces agricultural production, especially the main plantation Citrus fruits grown in the regions on the Mediterranean coast.

Climate factors such as drought are considered the principal factor that limits global agricultural production. Citrus species greatly differ in their ability to overcome water deficiency and environmental stress pressure. According to García-Sánchez et al. (2007) in long-term periods of stress, water deficiency or drought in citrus trees causes reductions in stomatal conductance (gS), leaf transpiration rate (E), and net CO_2 assimilation; decreases fruit quality and yield. Through the process of photosynthesis, plants absorb CO_2 from the atmosphere, transform it into plant carbon, and sequester it in either above- or below-ground biomass or soil carbon.

Climate change impacts on water resources have been mainly attributed to associated changes in climate variables of precipitation and temperature (Islam et al. 2012). Increasing temperature, drought and other abiotic stresses can significantly affect citrus cultivation and fruit quality (Yeşiloğlu et al. 2018). Under possible climate change pressure, crop yields may decrease by %11. Since soil and crop management such as tillage, water management and cropping system have an effect on soil degradation and CO_2 flux, it is important to monitor and measure CO_2 flux from the soil to the atmosphere for a better understanding of the terrestrial carbon stocks and cycle on climate change.

Soil degradation and increasing atmospheric CO_2 levels can increase temperature and cause water deficiency and consequence the yield is supposed to be decreased within time. In a model work, it has been estimated that an increase in air temperature by 2-3 ^{0}C, will decrease by 2070 wheat and maize biomass by %4 to %17 and water demean will increase (Aydın et al., 2011). Also, climate change has a great influence on pests, insects and other organisms (Hassan et al. 2023). Organisms directly and indirectly affect citrus production.

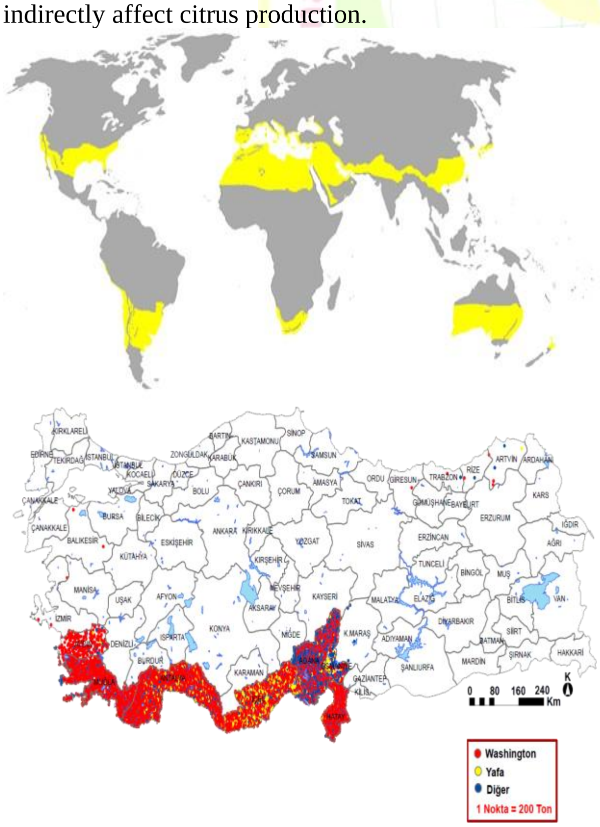

Figure 6. World citrus production map. A: World citrus-grown areas are shown with yellow color. B: Citrus production in Turkey

Table 2. From 1996 to 2021 Turkish citrus production area and product, yield (FAOSTAT, 2023)

Citrus Variety	Years	Area harvested	Yield	Production
		Hector	Kg/ha	Ton
Grapefruit	1961	237	10895	2582
	1970	304	23026	7000
	1980	630	26984	17000
	1990	1030	32039	33000
	2000	4680	27778	130000
	2010	6063	35258	213768
	2020	5378	44413	238012
	2021	5039	49415	249 000
Lemons and limes	1961	2877	24484	70440
	1970	4787	26321	126000
	1980	10767	26284	283000
	1990	14967	23853	357000
	2000	23085	19926	460000
	2010	25360	31036	787063
	2020	33628	35346	1188517
	2021	52233	26975	1 550 000
Oranges	1961	19180	9272	177836
	1970	24727	17997	445000
	1980	28847	23538	679000
	1990	32720	22463	735000
	2000	46300	23110	1070000
	2010	53236	32131	1710500
	2020	51000	28679	1333975
	2021	8177	36158	1742000
Mandarins	1961	5107	6659	34007
	1970	8127	8367	68000
	1980	12400	13468	167000
	1990	22860	15092	345000
	2000	27400	20438	560000
	2010	33289	25795	858699
	2020	50785	31275	1585629
	2021	60720	29957	1819000
Citrus Fruit, Total	1961	28604	10101	288931
	1970	39488	16605	655700
	1980	53661	21580	1158000
	1990	71944	20488	1474000
	2000	101706	21849	2222200
	2010	118105	30248	3572376
	2020	140792	34928	4346133
	2021	166169	46437	5360000

Citrus Growth Depend on Climate Conditions

Most probably, food security and production will be disrupted. For example, citrus growing areas in the sub-tropic belt will shift towards the poles. This is also true for many other products. Citrus fruit trees are growing in tropical and sub-tropical regions that require a suitable climate for quality production (Figure 6A). Citrus fruits are mainly produced in coastal areas in several countries as well as the Mediterranean region. The Mediterranean region has a semi-arid/subtropical climate and the region is an important area for citriculture production. Many Mediterranean countries such as Spain, Turkey, Italy, Greece, Egypt, Morocco, Tunisia and Israel have a high amount of high-quality citrus fruit production.

With the Climate Change, Would Citrus and Many Other Plant Species Grow in Anatolia and Sub-tropical Regions?

The main abiotic stresses in citrus cultivation. Turkey, situated between Asia and Europe, has 78 million hectares land, and separated seven geographic regions including, The Mediterranean, the Aegean, the Black Sea, Marmara, Central, South-eastern, and East Anatolia. According to the Ministry of Agriculture, there are 190 different agricultural basins in terms of rainfall, temperature, topography and soil characteristics and those could be aggregated into 30 different basins. In those agricultural basins above, 250 agricultural products are produced and marketed.

Table 3. Turkey, India and the world's citrus cultivation area, yield and production (FAOSTAT 2023).

Measurement	Fruits					Total	% of World
	Lemons and limes	Oranges	Pomelos and grapefruits	Quantity	% of World		
Area harvested ha	India	327000	694000			1021000	10.28
	Turkey	52233	48177	5039	60720	166169	1.67
	World	1338321	3932648	360892	3109051	9928082	
	Africa	125717	530388	56702	182221	895028	9.02
	Americas	453394	1422180	69256	258948	2203778	22.20
	Asia	672490	1681517	230379	2507087	5091473	51.28
	Europe	83299	275133	3690	152596	514718	5.18
	Oceania	3421	23431	865	8199	35916	0.36
Production Million tones	India	3.548	10.270			13.818	8.3
	Turkey	1.550	1.742	0.249	1.819	5.360	3.2
	World	20.829	75.568	9.557	41.950	147.904	
	Africa	1.833	10.068	0.873	3.452	16.227	9.7
	Americas	8.228	29.104	1.309	4.775	43.417	26.0
	Asia	9.093	29.356	7.267	30.401	76.116	45.6
	Europe	1.625	6.592	0.098	3.146	11.461	6.9
	Oceania	0.049	0.448	0.010	0.176	0.683	0.4
Yield kg/ha	India	10850	14798				
	Turkey	29675	36158	49415	29957		
	World	15563	19216	26482	13493		
	Africa	14581	18983	15403	18946		
	Americas	18149	20464	18908	18442		
	Asia	13521	17458	31542	12126		
	Europe	19507	23959	26537	20615		
	Oceania	14444	19114	11083	21471		

Luvisols/Red Mediterranean soils are the best citrus growing soils. Several rootstocks especially Carrizo citrange and mandarins are more common due to high soil pH levels in the Mediterranean region of Turkey. However, sour orange is the main rootstock in the Çukurova region. However, there is several soil and ecological factors limiting production such as; High pH (07 50-07.80), High CaCO3 (15-28 %) Heavy clay soil (25-55%) and soil structural development, High salinity (manly in south part of Çukurova Plane), Cold and frost and Zn, Fe and P nutrient deficiency. Of the total 78 million hectares of Turkish land, 35% belongs to agriculture that is 24.4 million hectares. Of the total arable land 67% is cropland, 17% is fallow land and the rest of them is cultivated for horticulture, vegetable, vineyards, olive garden and citrus orchards

Turkey is one of the important Citrus producing countries in the world as well as in the Mediterranean area. Turkey is the second-largest citrus-producing country in the Mediterranean basin and 7th larger producer in the world. Turkey alone produces 3.5 % of world citrus production. In 2021, the total citrus production of Turkey was around 5.36 million tons (Table 2).

The majority of citrus production (%75) is produced in the southern part of Turkey (cost of the Mediterranean) (Yeşiloğlu et al. 2018). Less citrus is produced in the cost of Black See coastal area. In Turkey, manly citrus production is orange and mandarin letter on lemon. From 1961 to 2021, citrus production is regularly increasing. Citrus production is more than county conception. Per person, citrus consumption mainly orange is around 25 kg. Citrus is the one of exporting cash crops in the Turkish economy.

Asia is only cultivated over 50 % of the total citrus cultivation area. Later on, the American continent, cultivated or diverted more land for citrus production. The homeland of citrus is Cinnamon, which alone provides the majority of production in Asia. Nearly 46% of world production is produced in Asia. Turkey has 166169 hectares of citrus cultivation area. Turkish citrus production area is 1.67 % of the world's citrus production area and Turkey is producing 3.2 %of the world's production (Table 3). India has more than 10 per cent of citrus cultivation and produces 8.3 % of the world's production.

Citrus fruit quality and quantity are affected by multiple factors such as climatic conditions. The global warming and drought problems have occurred in many citrus growing countries. Citrus production in these regions is affected by both biotic and abiotic stresses, including climate change extreme temperature, drought, salinity, heavy metals, nutrient stress, water stress, alkalinity and soil degradation. These stress factors can severely influence the growth, development of both rootstocks and/or scions of citrus trees. Abiotic stress factors also reduce fruit production and fruit quality as well. Under semi-arid soil conditions, citrus production is mainly affected by the amount of irrigation, drought, high temperature, soil type, soil nutrient supply capacity and fertilization. Citrus growth, fruit yield and quality are affected by genetic and environmental factors.

Since sour orange rootstocks are mycorrhiza dependent (Ortas 2012a), and under sterile conditions grown seedlings without mycorrhizal inoculation transplanting to field conditions, the mortality rate is higher.

The selection of the most effective AM fungi species for the growth and enhancement of Citrus cultivars used as rootstocks was the first step toward the development of an AM inoculation system in Citrus nurseries in cost of the East Coast of the Mediterranean part of countries.

Mycorrhiza makes plants resistant to stress factors. Also, since mycorrhiza demands more carbon from the plant, the plant fix more CO_2 from the atmosphere (Ortas 2012b). Therefore, mycorrhiza can mitigate the climate change effects on plants.

What are The Quantities and Possible Solutions for How Climate Change Will Affect Future Citrus Plantations

The cost of Mediterranean soils has heavy clay soils. Since citrus plants demand well-drained conditions, soil porosity and aeration are very important. Therefore, under heavy clay conditions, farmers are trying to have growth with backyard production systems. Since soils are heavily clayey, after transplanting the non-mycorrhizal inoculated seedlings developed their root system deeper in the soil profile for proper growth.

For a possible solution, the situation of climate change on citrus orchards and plant growth needs to be questioned.

Question 1. What are the possible effects of climate change on citrus growth?

The possible influence of global climate change on agriculture specifically on citrus production is related with;

-Precipitation and its distribution,
-Water availability,
-Drought conditions,
-Runoff,
-Potential evapotranspiration,
-Soil moisture changes are affected by global temperature and rainfall.

All are affecting agricultural production and food security. Climate change's global influence on sustainable agriculture depends on the efficient management of land use and freshwater resources. The possible effects of climate change in the Mediterranean region are expected to be; water deficiency and floodness. Recently our observations showed a long-term drought season and sudden heavy rainfall and flood conditions.

Soil moisture deficiency or flood conditions

Water security is a prerequisite for food security in West Asia, plant growth and food security depend on water security (rainfall quantity and distribution). The agroecosystems in the Mediterranean region (adapted from Ryan, Singh, & Pala, 2008).

Citrus plant's water requirements yearly range from 8000–10000 m^3/ha depending on different factors like precipitation, climate conditions, soil texture and other conditions, growth stage…etc.

Fluctuation and flood negatively affect citrus growth

There are various negative effects of a long drought period on the citrus trees including dropping flowers and new fruit set, also, new flushes and main branches are affected by drought conditions. Also, recently after heavy rain many orchards are under flood. As known citrus plants are non-tolerant crops for soil flooding. Under long-term waterlogging, various injury to the citrus tree especially under clayey soil conditions negatively affects citrus growth.

The two most serious problems of climate change are food security and the other one is water supply. Providing safe and sustainable water (water cycle) is the most important priority for the continuation of life. Since food and crop production is directly dependent on water use, water security is a prerequisite for food security.

For water and food security possible solutions to addressing the challenges.

In order to reduce the effects of climate change and global temperature on water deficiency and yield reduction several ways can be suggested.

The countries of the Middle East, Asia, and Africa are more exposed to environmental changes due to less preparedness and technology to tackle these issues.

Water supply
Water harvest
West water utilization
Manage ground water and aquifer
3. Improvement of irrigation efficiency (drip irrigation, partial root dry methodology)
4. Water resistance and water and nutrient use efficient genetic selection research
5. Drought-resistant citrus rootstocks and varieties.

Question 2. Negative Effects of Temperature Increases
-Temperature increases effects on soil doughtiness.
-Plant physiological operations?
-Will citrus and many other plant species grow in Anatolia under over +2 ^{0}C temperature?
-Citrus growing in warm climates from tropical to arid conditions in a wide range of temperatures ranging from 10˚C to 35˚C.
-With rising temperature more than 35˚C citrus growth can decline. The Mediterranean climate is considered the most suitable climate for citrus growth and productivity. In the region, sometimes temperature can increase up to over 40 ^{0}C.
-Cold and frost conditions burned citrus trees
-Citrus trees did not tolerate cold conditions or frost, while, they can withstand low temperatures up to 3˚C for a short period. Flowers and new shoots are burning under cold temperature up to (-1.7˚C), and the low temperature below (-6˚C) leads to burning trees.

Temperature, water and citrus growth

Citrus growth mostly depends on climate conditions and water availability. The yield of any crop tends to decrease when the temperature exceeds the ideal temperature range and the water level falls below the ideal water demand of the crop.

Temperature is changing plant physiology

The most important factors are fluctuating patterns of temperature and drought, which have an adverse effect on plants' physiology, morphology, water status, biochemistry, anatomy, genetics and productivity.

Effects of climate change threats and adaptations

Climate change especially drought and high temperatures collectively effects plant growth.

Threats/Problems:

Increased oxidative damage; decreased photosynthesis; reduced growth; increased sensitivity to drought; loss of production; salinization; crop soil deterioration. The risk of drought and desertification due to climate changes in the Mediterranean basin and up to inner Asia seems to have begun to affect agricultural production negatively. It seems that the risk of drought and desertification due to climate changes in the Mediterranean basin and up to inner Asia has begun to affect agricultural production negatively. Since the Mediterranean basin is a significant citrus production area, absolute production and management techniques should be applied to be less affected by climate change.

What are the possible adaptation ways?

Variety breeding;
Rootstock breeding;
Cultivation techniques;
Resource optimization

Question 3. Under climate change and temperature increases, will citrus and many other plant species grow in Anatolia under climate changes?
-Soil, crop and water management is important for keeping citrus growth under limited soil moisture conditions.
-No-tillage and reduced tillage are extremely important for water and nutrient protection for better growth.
-Mulching, keeping soil moisture
-Irrigation and fertilizer management
-Land use policy and orchards management are needed.
-Agriculture and forestry should be supported on a governmental level.
-Any possibility to reduce the effects of climate change on plant production?
-As known, environmental conditions and climate are constantly changing and plant species have always adapted to the changes.
-Some may have a large adaptation range and some have a small range.

Question 4. How big the climate change made soil salinization and degradation influence citrus production? According to Ruiz-Lozano et al. (2012) currently over 7% of the Earth's land area is estimated to have saline soils. Soil salinization and drought are major and growing limiting ecological problems. Salinity limits the productivity of crop plants cultivated on more than 20% of total agricultural lands worldwide (Ortas et al. 2021). Droogers et al. (2001) indicated that in India range from 27 to 60% of the total irrigated land, Iraq 50%, Egypt 30%, Australia 20%, China 15%, Pakistan 14%, 13% and 1,3 % of Israel soils are under salinization. Those countries at the same time produce citrus.

Question 5. Dose biotechnological work can help to develop new species resisting climate change.
Are necessary to study or develop climate-resilient citrus rootstocks and scion through genomics and biotechnology.
-Using proper rootstocks tolerant for drought and heat stress like Citrus limonia (Rangpur lime), and Citrus jambhiri Lush. (Rough lemon), minimizing the adverse effects of rising temperature, drought and salinity stresses (Cimen and Yesiloglu, 2015).

Question 6. The possible new habitat, which will be formed due to increasing climate changes, especially temperature and humidity will also change the population of diseases and pests. Plants may not be ready to propagate themselves against new species.
Cultural Precautions?

Therefore, the focus should be on creating agricultural systems that are more water-efficient and can adjust to hot and dry weather through agronomic practices. It is primarily necessary to create citrus rootstocks and scion that are climate robust using genetics and biotechnology. Citrus plants can be more resistant to biotic and abiotic stress factors by using rootstocks and scion selection. The decreasing order of salinity tolerance Cleopatra mandarin, Rangpur lime, Volkameriana, Sour orange, and C35 citrange rootstocks was reported (Darshan and Shukla 2021). Managements of plant-soil in terms of nutrient absorption related to soil organisms.

Irrigation with fertilizer is inevitable for citrus production such as;

-Citrus production in the Mediterranean region is increased, and the effect of fertilizer and water on yield and quality is important. Especially for citrus plants, the role of drip irrigation and fertigation systems is important. With increased drip irrigation and micro-irrigation activities, it is important to determine the best way of using fertilizer in fertigation.

-Management; such as the use of the new hormone, especially for flowering drop, irrigation and soil nutrients managements can be implemented to the citrus plantation regions. Water and fertilizer use is important for future citrus production under climate change. Water and fertilizer efficacy use and management is requiring high education, technology use and skill.

-New technology needs for wastewater as a source of water and nutrient. In the areas which are getting less precipitation, wastewater can be filtered and purified for agricultural use.

-Water harvest techniques are needed to be developed. In the Mesopotamian area, water harvest techniques are used to keep water for long-terms in summer. Especially half-moon water harvesting or rainwater can be harvested in the hollows around the tree plants.

-Nutrient managements such as Calcium (Ca), Potassium (K), Boron (B), and Manganese (Mn), adapt tree behaviour under stress through controlled stomatal conductivity under heat/high-temperature stress. Macronutrients protect plants against high temperature. For increased plant tolerance to the rising temperature, the use of macro elements particularly N, K, Ca and Mg is important which can minimize the injuries of reactive oxygen solutes.

Biological Control?

It might be necessary to create citrus species or cultivars that are climate change resistant. The safety of citrus production is especially ensured by the development of variants resistant to hotter temperatures and drought. Under field circumstances, biological control strategies such as the utilization of beneficial organisms can be used.

Biotechnological Studies?

Do New Technologies Need?

It is possible to maximize cutting-edge technologies such as current agricultural mechanization, soil, water, and crop management, organic and chemical fertilizers, novel varieties of seeds and rootstocks, and bio-nanotechnology.

Resistance to biotechnology in cultivar development or climate change in citrus species may open up new opportunities. It is possible to boost the ability of harmed bacteria. Growth Regulators OR bio-stimulants to increase plant physiological capacity against climate change. If yes? Which type of bio-stimulants can be used or suggested? Growth regulators can help plant increase plant tolerance to abiotic stress. Plant growth regulators like cytokinins (CK), abscisic acid (ABA), salicylic acid (SA), Jasmonic acid (JA), and Proline, could play a significant role in increasing citrus tree tolerance abiotic stress (Iqbal et al, 2019).

CONCLUSIONS

What we should do? What should be future citrus research strategies about climate change?

The unfair climatic crisis, whose nature has resulted in a decline in the economic and social order, has caused significant issues for humanity. We must transition to public economic models, cut back on consumption, and minimize waste in order to coexist with nature on decertified lands. It appears that significant plants in the area may experience additional severe issues as a result of climate change.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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