

Potential impacts of global climate change on citrus cultivation

Abstract

Climate change has a dramatic effect on growth and productivity of various crops, there are various environmental elements affect the life cycle of annual and perennial plants, like high temperature, heatwaves, drought, cool temperature and frost, rising carbon dioxide (CO₂) levels. Climate change represents a dangerous challenge for mankind, there need for an efficient strategy to guarantee adequate crop production for humanity.

Citrus is one of the main fruits all over the world, citrus can be grown in different climatic zones ranging from tropical, subtropical, arid and semi-arid areas, citrus grows properly in the range from 12.8 to 37°C, which considered the optimum temperature for citrus growth and fruiting, while, sever high temperature (above 44-45°C) stopped citrus growth completely. Low temperature considered the limiting factor for the geographical distribution of citrus, low temperature could stoop metabolism activity, whereas, chilling and frost cause severe injuries and demolish the whole tree. Temperature fluctuation affects negatively growth, decreases total yield, and reduces fruit quality particularly when occurred during the maturity stage, also, there are negative effects of heatwaves on the production of different citrus varieties particularly seedless varieties like Navel orange, and some Mandarin and lemon cultivars.

On another side, rising carbon dioxide has positive effects on the growth of citrus seedlings and trees productivity.

Keywords: citrus, climate change, temperature fluctuation, CO₂, yield, fruit quality

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Background

Citrus is one of the major crop all over the world, citrus ranking as third fruit crop after grapes and apple, citrus fruits are considered as essential family foods in different countries all over the world, more than 100 countries around the world,¹ besides, the citrus processing industry has a great value in the global market, due to high nutrition values of citrus juice for human health.

Citrus fruits native in tropical and subtropical southwest Asia, it's distributed in different worm regions of the world particularly arid and semi-arid climates under irrigation which represent the major areas to produce citrus like Delta region in Egypt, Florida and California in USA, Valencia in Spain, Sicily in Italy, and the Cukurova region in Turkey.²

Citrus can be grown in different climatic zones ranging from tropical, subtropical, arid and semi-arid, it's growing in a range of temperatures between 12 to 37°C. The low temperature and frost is the determining factor for citrus distribution due to its sensitivity to cool climate.⁴ Also, some citrus varieties could be grown in cool climate particularly when grafting on trifoliolate orange (*Citrus Poncirus*) rootstock.³

Climate change causes serious problems and represents a serious challenge for human civilization, particularly global warming which needs an effective strategy to guarantee adequate food production.

Nevertheless, it is well reported that high temperature reduces the growth of citrus trees due to decrease in net CO₂ assimilation, also, high-temperature increase fruit set abortion and accelerate dropping

of young fruit, Exposing citrus trees to high temperatures can lead to chlorophyll deficiency and reductions in photosynthesis.⁵

Citrus growth and production affected by different climate elements like low temperature and freezing, heat stress change, CO₂ assimilation, rainfall, heat waves, drought, or intensive rainfall and relative humidity, therefore, any change in climate elements affect directly and indirectly on citrus production.⁶

Climate variability characterized by heat stress and aridity probabilities has directly affected citrus production like in the Mediterranean region, and the fact is that climate change and variability will continue to affect citrus productivity in the coming decades through increased or more intense occurrences of extreme events, such as droughts, rising temperature, and storms.⁷

Citrus growers have to take steps to adapt to expected climate change in the future, they must decide to construct investments in the current time to balance negative impacts of climate changes on citrus orchards productivity and to cope with unfavorable conditions in the future and keep high production with proper quality.⁸

This work gives an overview of effect of climate change on citrus growth and productivity, of course, there is need for more research in the future to understanding the impacts of different climate factors on citrus productivity.

Citrus production regions

Tropical climate: Under tropics climate citrus fruit generally has poor quality particularly oranges and mandarins fruits, due to there is

no enough differences between day and night temperature, therefore peel always green and juice color is light yellow.⁹

Subtropical climate: In the subtropical climate there is more humidity, therefore, fruits are bigger, and have more juice, reach with total soluble solids but less bright color, this fruit appropriate for juice and concentration production.¹⁰

Arid and semi-arid climate: Currently considered the main region for citrus production like the Mediterranean climate which has low night temperature and proper humidity which produce luxuries fruits with bright color and smoothly taste, therefore, much of the citrus production in this area is for export to global markets for fresh consumption and the rest for the local market.¹¹

Effect of climate on citrus growth and fruit characters

Climate has a notable effect on citrus growth, productivity and fruit quality, temperature between all the factors plays an essential role in determining the quantity and quality of the fruit and final yield,

rising temperature during fruit drop period cause lose great ratio of total yield,¹² while, there are adverse effects of high temperature and drought conditions on fruit maturity like delay fruit maturity, demolish the peel color, increase fruit splitting and creasing, so, decrease total yield.

Effect of climate change on citrus flowering

In Northern hemisphere flowering occurs once in spring yearly, its intensity and longevity are regulated by temperature, the subsequent fruit growth until early autumn, however, fruit ripening in early cultivars like Hamlen orange could occur as soon as Mid of October (Figure 1) {Photo 1a} while in late varieties like Valencia orange it can be expanded until the March or April of next season {Photo1 b}.

However, in the tropical regions flowering occurs all over the year, therefore, different fruit growth stages and flowering found on the same tree, which may cause complexity in determining fruit ripening and proper harvest time.¹³

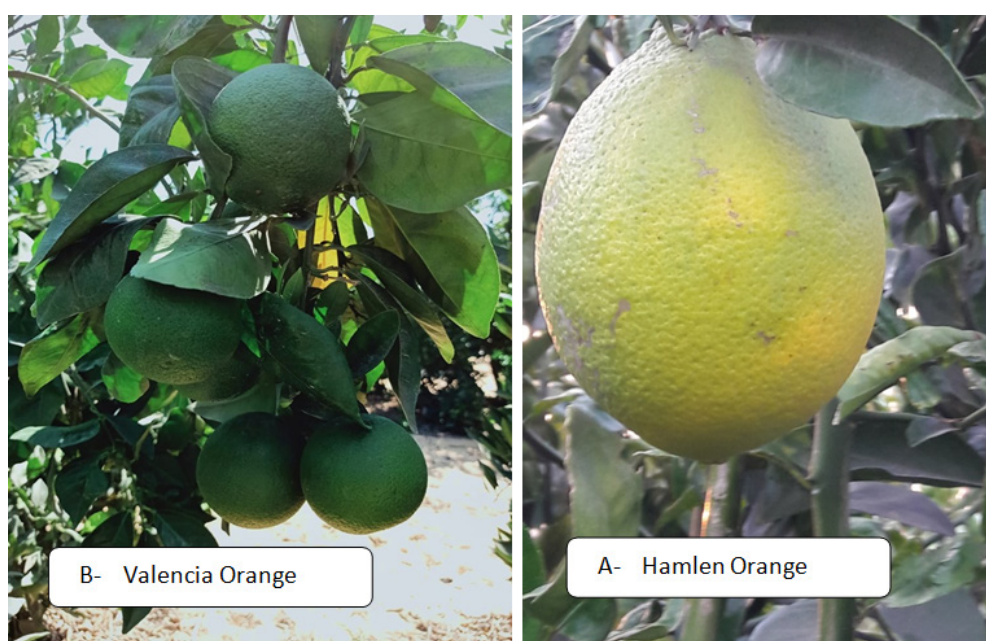


Figure 1 Field image of early Hamlen orange and late Valencia citrus fruits, October 2019, Egypt.

Effect of climate change on fruit set

In general, fruit set depends on successful pollination and fertilization, rising temperature affect negatively on flowering cause abscises of flowers, and reduce fertilization, apportion fruit set and could dropping more fruitlets particularly in seedless varieties.¹⁴ Generally, rising temperatures will inevitably lead to reduce the final yield of different citrus varieties.

Effect of climate change on fruit growth

Fruit growth: it's well reported that the growth of citrus fruit separated for three different stages, also, citrus fruit growth follows a sigmoid growth curve typically,¹⁵ there are numerous endogenous and exogenous factors determined fruit setting or abscission during different growth stages.

There are various factors affect flowering, fruit set and total yield

like cultivar, tree nutrition statues, tree age, environment conditions, pests and pathogens, for example, rain precipitation injured yield of late mature varieties, its increase the spreading of fungal pathogens like fruit rot, besides difficulty in harvesting and other agricultural practice.¹⁶

Temperature and citrus trees

The optimum temperature for citrus growth and fruiting from 13 as a minimum temperature to 37°C,¹⁷ while, 12.8°C considered the proper temperature to recovery citrus activity and start new growth cycle,⁷ soil temperature affect citrus root growth, it must be over than 12°C for bud emergent and recovery tree activity,¹⁸ on the other hand, low temperature is the limiting factor for citrus growth, therefore, the metabolism activity stooped when temperature lower than 10°C, while, chilling and freezing cause serious injuries and destroy the whole tree.¹⁹

Therefore, under climate change conditions non-ideal temperatures reduce citrus growth rate or stop growth completely, also, fluctuations of temperature during the reproductive period particularly in cell division and cell elongation could prevent the final crop.²⁰

High temperatures

Exceed high temperatures in winter season during flower bud initiation reduce conversion rate to flowering buds and increase vegetative bud ratio which reduces the final fruit yield of trees particularly in non-seed varieties like Navel orange, especially with the exposure of additional stress like drought. High temperature over 37°C causes serious effects on the growth and productivity of citrus trees particularly under drought conditions, also, intensive radiation during high temperature reduces fruit set and increase fruitlets drop, and excessive temperature between 44-45°C can slow down fruit growth and cause serious fruit abscission,²¹ also, the improper temperature had directly adverse effects on citrus fruit characters including coloring disorder, enlargement, reduction insoluble solids and increase acidity, sunburn which considered a direct disorder of rising temperature of the fruit surface temperature, also, there is a positive correlation between rising high-temperature and spreading of pests and diseases.²²

Low temperatures

Low temperature considered the main restrictive factor for citrus distribution worldwide, generally, low temperature reduce growth of citrus and reduce productivity, as mention above citrus growing in temperature limit between 12.8 and 38°C, therefore, low temperature below 13°C limited vegetative growth and fruit growth, and delay maturity,²¹ however, forest destroy yield and if it remains for long-duration could killed the whole tree, especially in the arid and semi-arid regions.⁹ It has known that accumulation of pigments such as anthocyanin and carotenoid in pericarps is generally advanced under low temperature, the harvesting period of citrus fruit is often determined by the degree of coloring, the delay of peel coloring considered the determining factor of the harvesting period.²³

Effect of heatwaves

Heatwaves increased over the current decade with probability to increases in the next decades, these waves characterize by rising temperature over 30c and excessive solar radiation, and it could be extremely dry or humid, in summer 2018 the Mediterranean area hit by a heat waves affected negatively on different crops,²⁴ also, this year (2019) the citrus production in Spain decreased by 17% approximately due to rising of temperature and hitting by heatwaves which affect final yield of citrus in the whole Mediterranean area.

Heatwaves affect the production of different citrus varieties particularly in seedless varieties like Navel orange, Shamouti orange, some Mandarin and lemon cultivars, the sever effect of hot waves is clearly during the flowering and fruit set stage, and secondly during the June drop.

Effect of CO₂

Increasing carbon dioxide levels in the atmosphere have more attention in different climate change research, due to their effects on global warm, however, there are positive effects of increasing CO₂ levels and growth of citrus seedlings and productive trees, there are a large number of studies have been conducted on responses of various types of crop systems to elevated CO₂.²⁵

Koch et al.,²⁶ reported that growth of Carrizo citrange seedlings improves under of elevated CO₂ conditions, also, elevated CO₂ under high-temperature conditions improve vegetative growth and total yield of young sweet orange (*Citrus sinensis*) trees.

There is a positive response of sour orange (*Citrus aurantium* L.) seedlings and trees to increasing CO₂ level, which improves the biomass growth of trees to 2.3-fold for fine root mass and 2-fold more branches, 1.75-fold of leaves, trunk and branch volume bigger to 2.6 fold.²⁷

Also, the growth of Eureka lemon citrus trees (*Citrus limon* L.) increases up to 21% under elevated CO₂ and low temperature, however, high temperature with CO₂ elevated improve growth to be 87% more than trees growing under normal conditions.²⁸

More research required to explain phenological changes occurring in the tree as a result to increase CO₂ levels in different cultivation areas.

Temperature and fruit color

Cold air temperature is the main factor during maturation period of citrus fruit for accelerating chlorophyll reduction and increase carotenoids which require low air temperature during the complete day (24h) in addition to cold soil temperature,²⁹ generally, its well reported that color break start with low temperature about 12.8°C.³⁰

From another side, the rising temperature during maturity stage reduces color break and producing green fruit,³¹ and warm night temperature has more influence than day temperature.³²

Temperature and fruit cracking

Fruit cracking represents one of the main problems for citrus growers in arid and semi-arid areas under climate change like increased fluctuations in temperature and relative humidity, besides, warm night temperature which adversely affects fruit growth particularly after June drop.

High temperatures and drought increase fruit cracking and creasing (Figure 2), also, soil moisture both too much watering and drought affect fruit cracking particularly during heat waves increase fruit splitting. Fruit cracking mostly occurs in navel oranges such as 'Washington', and mandarin hybrids like 'Murcott', 'Nova'.³³



Figure 2 cracking in Valencia fruits {Egypt 2019}.

Temperature and fruit drop

Climate change affects negatively on total yield, and deteriorations fruit quality of citrus, also, there are various reasons for fruit drop including nutrition statuses, shortage in carbohydrate, heavy fruit set, drought, hot temperature, and abiotic stress,³⁴ high-temperature during June drop increase fruitlets drop and decrease fruit growth particularly in varieties trend to alternate bearing,³⁵ while, severe temperature about 44-45°C cause serious fruit abscission and reduce final yield.²¹

Conclusion

Climate change affects growth and productivity citrus varieties particularly seedless varieties, different environmental factors like high temperature, heatwaves, drought, cool temperature, and frost, has an impressive effect on growth and productivity of citrus, while rising carbon dioxide (CO₂) levels improve citrus growth and productivity.

The optimum temperature for citrus growth and fruiting ranged from 12.8 to 37°C, however, heatwaves and severe high temperature affect the production of different citrus varieties particularly seedless varieties, whilst low temperature minimize metabolism activity, whereas, chilling and frost for long period could destroy the whole trees, from another side, rising carbon dioxide has positive effects on growth of citrus seedlings and productive trees.

Generally, there are adverse effects of temperature fluctuation on growth, and productivity of citrus orchards.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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