Climate Change Challenges in Temperate and Sub-Tropical Fruit Tree Cultivation

Subjects: Agronomy

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In the last few years, the world has experienced the impacts of climate change, such as elevated mean annual temperature, extreme weather events, drought, etc. Among living organisms, perennial plant species are the ones mostly exposed to climate change impacts, as they may experience different extreme events within the same year, such as flooding during some periods and drought in summer months, extremely low temperatures in winter but excessively high temperatures in summer, etc. Climate change affects a range of physiological functions of temperate fruit and nut tree species, such as their phenophases, bud dormancy release and vernalization, pollination and fruit set, fruit growth and quality, as well as bud sprouting and growth initiation. Besides these, the impact of climate change on pests, diseases, and weeds may generate significant negative interactions with tree physiology, threatening food production, food safety, and human welfare. In the present manuscript, a general aspect of climate change impacts on fruits' and nut trees' physiological functions is described and commented on.

Keywords: dormancy ; flooding ; pollination ; quality ; rainstorms ; vernalization ; yield

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Climate change or, probably by now, climate crisis's effects have been well documented in the last few years of human history [1]. According to NASA, climate change is defined as "a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates, having a broad range of observed effects that are synonymous with the term" [2]. According to the United Nations Framework Convention on Climate Change (UNFCCC), it is defined as "a change that is attributed directly or indirectly to human activity which alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable periods" [3][4]. Even if the earth's climate seemed quite stable during the pre-industrial period, changes have been taking place, mainly due to natural causes such as volcanic eruptions, solar storms, orbital activity, etc. [5][6][7]. After the industrial period, though, climate changes became mostly driven by anthropogenic activities, which, among others, include fossil fuel burn, vehicular and industrial emissions, land use change, and forestry, especially deforestation and degradation [8][9][10][11][12]. Such activities emit Greenhouse gases (GHGs), which can absorb infrared radiation and trap heat in the atmosphere [5], leading to global warming. The major GHGs are carbon dioxide, methane, nitrous oxide, and ozone, with CO_2 being responsible for 70% of the potential of raising the earth's temperature [8][9][12][13]. Among others, the receding of the arctic cycle diminishes its ability to reflect the sun's irradiance, thereby cooling the earth, keeping the sun's heat energy in the earth's environment, contributing further to global warming [9].

Without implementing any significant mitigation measures (carbon trading seems a solution, but more drastic and direct measures need to be taken), the global temperature is likely to climb by 1.5 °C in the near future (between 2030 and 2052) [12][14][15][16][17], while an increase of approximately 1.4–5.8 °C till the end of the twenty-first century is a potential scenario, too [8][16]. Some authors indicate that the planet's temperature has already risen by 0.6 °C [8], while others report an increase of 1.5 °C in the Mediterranean basin compared to the pre-industrial levels [18].

Climate change is expected to cause a series of phenomena with variable degrees of hazards other than the increase in temperature, such as erratic rainfall patterns and an increase in the frequency of extreme events such as heat or cold waves, frost days, droughts, floods, etc., even in the same area within the same year [3][8]. In fact, in 2023, Greece experienced two giga-forest fires and one extreme flood event, covering a vast area in water for months (**Figure 1**). The consequences of such disastrous phenomena are economic losses, social inequality, and ecological destruction which, all together, threaten human welfare.

Figure 1. A giga-forest fire in “Dadia Forest” (northern Greece) in the summer of 2023 (**above, left**) and a flood event in Thessaly prefecture (central Greece) in the autumn of the same year (**above, right**). The remains of an olive tree trunk the spring after the summer fire. (The photo on the right above is courtesy of Mr Bartzialis Dimitrios; the rest of the photos are from personal archives).

In climate change research, vulnerability is referred to as “the degree to which a system is susceptible to and unable to cope with adverse effects of climate change variability and extremes” [19]. Among the sectors most vulnerable to climate change is agriculture, which has faced a lot of challenges in recent years [20]. As climate plays a vital role in defining the geographic distribution of the various plant species [21], climate change has impacted agricultural production all over the world [22]. This is mainly due to changes in the mean as well as the minimum and maximum temperatures, in rainfall pattern and height, as well as in newly presented biotic threats (pests and microorganisms) [16] threatening plants’ adaptability and survival. Recently, the term “winter weather whiplash” has been adopted by the scientific community to indicate the range of extreme as well as rapid shifts in weather conditions (from hot to cold, from drought to extreme rainfall, and vice versa) which may induce severe damages to all living organisms [12]. Unlike other organisms, plants are the most vulnerable to extreme climate events, as they are unable to escape from the stress factor by moving or migrating to the most favorable environments [16]. There are differences even among plant species, as perennials are experiencing multiple stress factors during their lifespan, either separately (even in the same year) or at the same time. On the other hand, farmers of annual crops have, to some extent, the power to overcome the negative impacts of climate change by sowing or transplanting either earlier or later. In any case, though, as global temperatures continue to increase, some crops are expected to face a yield decrease ranging from 30 to 80% by the end of this century, the extent of which depends on the pace of temperature increase [23].

Nonetheless, some areas may probably benefit, to a small extent, from climate change while others will not, but from a global perspective, the earth’s environment will face a great challenge. Any changes in the climatic suitability of an area for specific crops to grow and produce suggest that there will be no single “loser” or “winner” as a lot is expected to change regarding fruit tree production.

The objective of the present review focuses on presenting the possible effects of climate change on the physiological functions of temperate fruit trees, productivity, and fruit quality, as well as on both abiotic and abiotic threats.

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