CLIMATE CHANGE: GROWTH AND PRODUCTION OF CHERRY – A REVIEW

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Abstract: The climate change issues are the utmost concern for humankind and decrease in plant production. Some scientific research work have documented the negative impact of climate change on human beings, flora, and fauna. The climate of Pakistan is also becoming more vulnerable due to an increase in sweet water scarcity, frequent heat waves, rise of sea level, which is threatening to the coastal environment issues. Climate change threatened the growth, development, and production of plant species. The changes in climatic conditions due to environmental degradation and industrial and urbanization activities decline the quality of fruit and yield of cherries around the world.

Cherries are deciduous flowering fruit tree species and popular among consumers due to their sweetness, visual skin colour, flavor, biological, ecological, pharmaceutical potential, and many health benefits all around the world. In addition, the availability of main phenolic compounds in cherries helps with full responsibility in solving the health issues traditionally since ancient times. Cherries also have a key position in the economic market, both at the regional and international level. The presence of soluble sugar and organic compounds in sweet cherries demands that farmers increase their cultivable areas in different countries, including Europe, the Mediterranean, Asia, the Far East, and Pakistan.

The review provide information about the role of climate change on cherry development and production, which was gathered from the articles published in various scientific journals through internet English databases, such as Liebertpub, CABI digital library, PubMed, Google, Google Scholar, and Science Direct, covering a period from 1952 to 2024. This study may be promising for the farmers, plant ecologists, researchers, horticulturists, land managers, mass media, and NGOs working for the improvement of cherry growth and production under the current changing climatic conditions.

Keyword: cherries, ecologists, environment, flavonoids, global warming, nanotechnology, soil quality.

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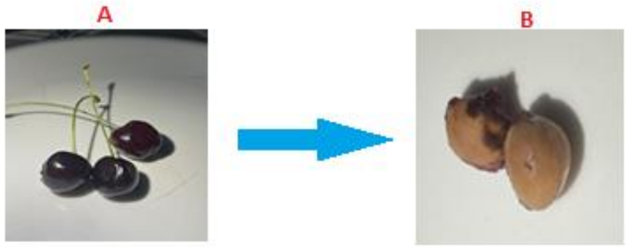

Figure 1. Cherry fruit (a) and seed (b) (Photo by Abdul Basit).

INTRODUCTION

Cherries as fruit trees with two types such as sweet cherry and tart cherry are popular in temperate region of the world. There are also different types of varieties of cherries are cultivating in temperate and subtropical environment around the world. Dzhuvinov and Kolev (2009) recorded nine sweet cherry cultivars. The cherries fruits are considered to be a good source for all the essential nutrients with many beneficial properties to human (Ballistreri *et al.,* 2013). Sweet cherries are primarily grown for fresh usage and tart cherries are processed as dried, juice, or frozen (Loescher, 2016). Cherries are popular with the name of “diamond fruit” with source of 52 aromatic compounds (Mei *et al.,* 2024; Wang *et al.,* 2024). Sweet cherry with bright red color, and in 2020, a total of 2.6 million tons were produced worldwide (Chezanoglou *et al.,* 2024).

Climate change responsible to increase the temperature, heat wave, sea level, changes in precipitation and ultimately these factors are responsible for influencing on plant growth. Climate change play an important role in increasing drought, loss of species, more health risks leads to poverty and displacement of flora and fauna of the disturbed region / ecosystems. A better agricultural management conservation, reliance on fossil fuel, industrial solution required to safe the cherries growth. However, in some cases the fruit has a limited shelf life of 7–10 days and loss of firmness, colour and flavour (Wani et al. 2014). The accumulation and transportation of pesticides and fungicide in plants can provide valuable insights to assess potential risks on food safety. The uptake of mandipropamid in cherry radish was reported rapid with bio concentration factors of 1.1–10.7 (Ye *et al.,* 2024).

The researchers around the world is working in examining the impact of climatic disturbances on cherries growth. A valuable insights into understanding about these changes through long term records of the timing of cherry blossom in Japan (Primack *et al.,* 2009). The constant threat to agricultural development, energy, ecosystem processes, environmental stress, natural resources, marine biota because of increased of atmospheric CO_2, external temperature, ocean warming, rise in sea level, soil fertility, acidification and decreased carbonate saturation due to climate change (Byrne, 2012; Thornhill *et al.,* 2016) strongly impacts on crop productivity, yield (Janni *et al.,* 2024; Hou *et al.,* 2024) and can lead to significant economic losses for farmers (García-Locascio *et al.,* 2024). Climate change and the growing world population leading to agriculture and food safety challenges (Wang *et al.,* 2022; Kukrety *et al.,* 2023). The declining soil fertility, macro and micronutrients, and improper use of different agrochemicals in agricultural sector is currently experiencing a severe crisis (Khan *et al.,* 2023).

The climate change, environmental pollution, soil qualities due to automobile, industrial, high rate of population growth, urbanization and anthropogenic activities and drastically damaging the crop productivity issues in developing counties likewise, Pakistan at alarming scale. The farmers are now accepting the new tools and technologies likewise nanotechnology, for the increase of crop productivity. Recently, the application of nanotechnology emerges as an important way to safeguard global food security and lessen the impacts of climate change (Tang *et al.,* 2023) in agriculture system. In this context the potential uses and benefits of nanoparticle based fertilizers in sustainable agriculture was discussed by Basavegowda *et al.,* (2021) and (Fincheira *et al.,* 2021). In addition, the impact of climate change on phenology, pollen, water and gas exchange parameters, fruit production, moisture stress, adaptation to biotic and abiotic stress and change scenarios for pest and disease modelling were also reported earlier (Hirschi *et al.,* 2012; Singh *et al.,* 2012; Sthapit and Scherr SJ, 2012; Nath *et al.,* 2019; Singh *et al.,* 2021).

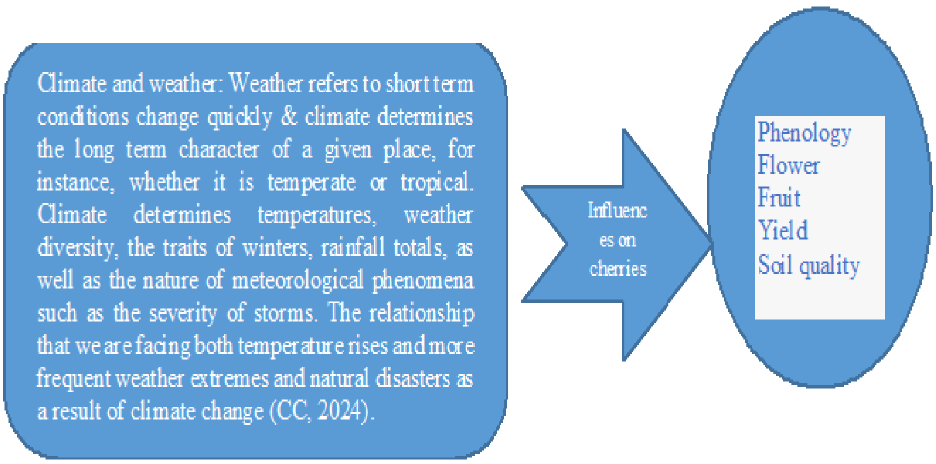

Figure 2. Climate change influence on aerial part and soil.

Climate change imposes various environmental stresses which substantially impact plant growth and productivity. Mariyam *et al.,* (2024) examined the environmental stress tolerance in plants. The global agro farming industry is facing many environmental complications and the agricultural regimen is becoming the "head honcho" of the world and imposed a grave danger to the environment and human civilization (Behl *et al.,* 2022). Duro *et al.,* (2020) predicted the increase of food consumption demand in between 58–98% for the world population which is expected to reach 9.7 billion in 2050 and 11 billion in 2100 that need innovative and sustainable solutions to meet the growing need for food worldwide in future (Guleria *et al.,* 2023).

The demands for more cherries production in recent year is increasing due to high public demand and population growth. Table 1 described the botanical feature of cherry (*Prunus avium* (L.) Moench) and growth around the world (Table 2). This review was aimed to provide relevant, meaningful and up to date information on cherries growth and production within the influence of variable climatic conditions in developed and developing countries including Pakistan. The obtained review data would be helpful for researchers, business, commercialization and professionals working in agriculture and food sectors and this review covered the scientific literature published during the period of 1952–2024.

Table 1

Botanical description of cherry (Prunus avium L.)

Domain	Eukaryota
Kingdom	Plantae – plants
Phylum	Spermatophyte
Subphylum	Angiospermae
Class	Dicotyledonae
Order	Rosales
Family	*Rosaceae*
Genus	*Prunus*
Species	*avium*
Botanical name	*Prunus avium* L.
Varieties	Black Star, Blaze Star, Burlat, Donnantonio, Ducignola Nera, Early Star, Ferrovia, Gabbaladri, Genovese, Giorgia, Grace Star, Maiolina Grappolo, Maredda, Minnulara, Moreau, Napoleona Forestiera, Napoleona Grappolo, Napoleona Verifica, Puntalazzese
Common name	Cherry, wild cherry, sweet cherry, diamond fruit,
Cultivars	Nalina', 'B. Burlat', 'Summit', 'Sunburst', 'Lapins', 'Kordia', 'Regina', 'Katalin', 'Hudson'.
Tree	Tree to 35 m tall while, nranchlets glabrous, green when young becoming red-brown and shiny.
Leaves	Leaf blade ovate to obovate or oblong, 3-16 x 2-8 cm, Petiole 1-7 cm long usually with 2-3 glands towards the apex, glabrous.

Table 1 (continued)

Flower	Flowers 1.5-3 cm in diamete. Stamens 20-35, filaments ca. 6-7 mm long. Ovary glabrous; style ca. 7 mm long, glabrous.
Climate	Prefers temperate
Fruit	Fruit a drupe, red to purplish black, shiny, smooth, 6 mm across.
Bioactive compounds	Glucose, malic acid, rich in minerals, phenolic compounds, vitamins, sugars, carotenoids, organic acids.
Pharmaceutical properties	antioxidant, antimicrobial, anti-diabetic and anti-cancer effects. and treatment of a wide range of diseases such as diabetes, diarrhea, gastrointestinal disorders, fevers, rheumatic pain, skin and urinary tract infections, kidney, liver diseases and sunstroke.
Geographical distribution	Chile, China, Europe, Iran, Japan, Pakistan, SW Asia. Mountainsides of the Etna volcano (Sicily, Italy). Turkey, USA, Uzbekistan.
Diseases	Postharvest black spot disease in cherry tomatoes. Easy to soften and rot. *Alternaria alternata*, black spot.
Miscellaneous uses	wood used for furniture making.

Dzhuvinov & Kolev, 2009; Ballistreri *et al.,* 2013; Dinda *et al.,* 2016; Chezanoglou *et al.,* 2024; FOP, 2024; Iqbal *et al.,* 2024; Mei *et al.,* 2024; Nejad *et al.,* 2024; Raynaldo *et al.,* 2024; Wang *et al.,* 2024.

MATERIALS AND METHODS

The growth and devlopment performances parametrs of cherry around the world in changing climatic conditions was searched from the research articles published globally in different scientific internet English databases, such as Liebertpub, CABI digital library, PubMed, Google, Google Scholar and Science direct covering a period from 1952 to 2024. The AMA reference citation style was used. The keywords which includes, antioxidant; bioactive compounds; biological activity; cherry fruit; cancer; chemical structure; climatic conditions; diabetes; environment; global warming; health; human; inflammatory; nanotechnology; phenology; phenolics; pollution; seeds; soil quality; terpenoids. The 800 documents written in English language were analyzed and of them 97 research articles were finally selected for review and included in the reference list.

HISTORY AND ECONOMIC IMPORTANCE

Cherries have a storied history that dates back to ancient times with significant cultural importance across the globe originated from the regions of the Black Sea, Caspian Sea whereas, this was first cultivated in modern day Türkiye and ventually spread to Europe by the Romans and North America with the early settlers (TG, 2024). The Government of Pakistan has taken many step towards enhancing the cherry industry in Pakistan. Presently, Pakistan is the 49th largest cherry producer globally with significant cherry clusters mainly in Gilgit-Baltistan, Baluchistan (PHDEC, 2023).

IMPACT OF CLIMATE CHANGE ON PHENOLOGICAL CHARACTERISTICS

Phenology response dominantly differ to ecological factors. The impact of global warming on plant phenology in Monsoon Asia reviewed for flowering dates of cherry blossoms with reference to the previous studies in Japan, Korea and China which indicated that the effects was due to urbanization (Yoshino and Ono, 1996). It was shown that the mean flowering dates of cherry blossoms in Japan and Korea become 3–4 days earlier when mean air temperature of March increased 1°C based on temperature and phenological data was observed at 82 stations in Japan for 68 years comprising 1953–2020 (Masago and Lian, 2022). Plant phenology in terrestrial ecosystems is expected to change owing to the projected increasing frequency and intensity of climate extremes in the context of global warming (Hongchao *et al.,* 2023). Blanke and Kunz, (2017) used 30 years of phenological data on climate change effects throughout Europe. The results of the phenological data of the last 15 years (2002 to 2016) with earlier data (1978–1995) showed 4–5 days earlier flowering (F1) in "Burlat" cherry. The changes in phenological timings of leaf budburst of cherries with climate change was also recorded in Japan (Doi and Katano, 2008). In addition, Saitoh *et al.,* (1996) reported the results of field observation and three dimensional computer simulation of the urban heat island in the Tokyo metropolitan area and predicted for an energy release rate five times which corresponds to the year 2031. The potential to record flowering patterns was studied in Japan within an iEcology framework, by collecting images from the SNS Flickr over the time period of decade 2008–2018 (ElQadi *et al.,* 2023).

IMPACT ON VEGETATIVE GROWTH, YIELD PRODUCTION AND FRUIT QUALITY

The yield of cherries may be threatened in warmer growing regions by insufficient dormancy, which usually occurs in late blooming genotypes (Holušová *et al.,* 2024). In Spain, Palencia *et al.* (2013) conducted research on yield efficiency of strawberry cv. Camrosa with relation to temperature (Ta) and sun radiation. At 15ºC – 20ºC a higher yield (80 g/plant) was obtained. Total yield start to decline as mean radiation exceeds 25 mJ/m^2. A temperature rise of 0.7–1.0°C could change the area currently suitable for the quality production of *Dashehari* and *Alphonso* mango varieties (Ahamed *et al.,* 2011). A linear rise in temperature which has made climate change an issue for civilization and according to research of 24 locations around the world the three sites – two in India (Bagalkot and Uttar Pradesh) and one in Argentina – displayed trends towards extremely high temperatures, which considered may be the reason of reduce banana growth (Coakley *et al.,* 1999). The imbalanced temperatures causes heat stress, inadequate chilling for temperate crops (IPCC, 2014).

The quality of the product can be characterized by various traits depending on the fruit and vegetable species and their edible parts such as fruit, leaf, root (Christopoulos and Ouzounidou, 2021). The fruit quality, production, fruiting ability and reduction in fruit size, pest incident and higher pest attack due to climatic changes (Jangra and Sharma, 2013; Bhattacharjee *et al.,* 2022). Changing climatic scenarios are impacting the pigmentation and secondary metabolites production to produce quality fruits, lower quality of grapes, (Hayhoe *et al.,* 2004; Rajan, 2008; Kizildeniz *et al.,* 2018). An increase temperature of 1°C can change the tropical region with greater impact on reproductive biology of the crops (Calberto *et al.,* 2015).

CLIMATE CHANGE IMPACT ON POLLEN AND FLOWERING DEVELOPMENT

Plants are finely tuned to the seasonality of their environment, and shifts in the timing of plant activity (phenology) are being influenced by global environmental change (Cleland *et al.,* 2007). Temperature stress seriously affects the disruption of pollination activity, which accounts for 35% of the world's food production (Gordo and Sanz, 2005). Temporal changes are already visible as *Apis mellifera* accelerated their activity period earlier than their preferred forage species flowering peaks (Dinesh and Reddy, 2012). Crop plants which are self incompatible, pollinator limited, pollinator specific are more vulnerable to this threat. Rising temperatures can hasten panicle growth and reduce the number of days available for successful pollination during mango panicle development (Chadha, 2015).

Climate change is affecting on flowering development on worldwide scale. Flowering is a critical stage as a result of warmer temperature for fruit development, undeveloped pistils in apricot and grapes (Brown, 1952; Rodrigo and Herrero, 2002); Miller *et al.,* 2007). An increase of 0.45°C/decade (1973–2009) in early spring temperature led to an advance in apple and pear blooming by 1.6 days/decade in South Africa (Grab and Craparo, 2011). Hsu *et al.*, (2023) recorded the historical bloom data of a flowering cherry (*Prunus × yedoensis*) from multiple locations in Japan across a latitudinal gradient based on advances (–) or delays (+) of bloom dates per degree Celsius of change (temperature sensitivity, ST).

Impact of climate change on kinnow fruit industry of Pakistan observed (Nawaz *et al.*, 2019). The potential vulnerability of Moroccan apple orchard and banana in Rome, citrus in Iran, apple production in Kullu valley of Himachal Pradesh (India) and grapevine in Italy was recorded (Tomasi *et al.,* 2011; Jangra & Sharma, 2013; Fitchett *et al.,* 2014; Calberto *et al.,* 2015; El Yaacoubi *et al.,* 2020). Grape wine, Aonla, apple and strawberry yield was damaged (Ahmed *et al.,* 2011; Palencia *et al.,* 2013; Haldankar *et al.,* 2015; Rai *et al.,* 2015; Kizildeniz *et al.,* 2018).

IMPACT ON PEST AND DISEASE INCIDENCE

Climate change has altered the occurrence of pest and disease in fruit crops and temperature fluctuation can result in the introduction of new pests, minor pests gaining major pest status, and breaking of resistance. The frequent occurrence of stormy rains leads to increased bacterial gummosis of pome and stone fruits (Ghini *et al.,* 2005). Climate change can alter pathogen development stages and rates, as well as host resistance and the physiology of host-pathogen interactions (Feichtenberger *et al.,* 2005). Climate change could lead to changes in geographic distribution, population growth rates, crop pest phenology synchrony and increased the risk of invasion by migrating pests and interspecific interactions (Nawaz *et al.,* 2019).

Table 2

Impact of climate change variability on aphid, bugs and different parts of plant.

Climate stressful action	**References**
Impact deciduous fruit production in California.	Brown *et al.,* 1952
Variation in the average yield of Cox's Orange Pippin apple in England.	Jackson & Hamer, 1980.
Pre-harvest exposure to sun influences postharvest of 'Hass' avocado fruit.	Woolf *et al.,* 1999
Impact of sun exposure on harvest quality of citrus fruit.	Woolf *et al.,* 2000
Plant growth temperature affected on antioxidant capacity in strawberry.	Wang & Zheng., 2001
Pre-blossom temperatures influenced on flower development and fruit set in apricot.	Rodrigo & Herrero, 2002
Average temperature of different day intervals of chill and heat effect blooming date.	Alonso *et al.,* 2005
Apple production and diversity decreased in Kullu valley, Himachal Pradesh (India).	Sen *et al.,* 2005
Temperature affects color and quality characteristics of 'Pink' wax apple fruit discs.	Pan & Shu, 2007
Importance of pollinators in changing landscapes for world crops.	Klein *et al.,* 2007
Physiological disorder in Litchi.	Kumar & Kumar, 2007
Global warming influenced on a group of related species and their hybrids: cherry tree (Rosaceae) flowering at Mt. Takao, Japan.	Miller *et al.,* 2007
The use of land change on the pest status of rice and fruit bugs (Heteroptera) in Japan.	Kiritani, 2007
Dormancy in apricot flower buds in two Mediterranean areas: Murcia (Spain) and Tuscany (Italy).	Viti *et al.,* 2010
The cracking and sunburn in litchi and integrated management to minimize the disorders.	Mitra *et al.,* 2010

Table 2 (continued)

The challenge of adapting grapevine varieties.	Duchêne *et al.,* 2010
Effects of climatic condition on off-season mangosteen production in Phatthalung Province. Songkhla:	Sdoodee *et al.,* 2010
Litchi and longan thrive in warm subtropical to tropical climates. Longan is sensitive to temperatures below 0°C, and temperatures ranging from -2 to -3°C can harm or kill young trees. Rambutan thrives in warm tropical regions with temperatures ranging from 22 to 30°C, but it is susceptible to cold below 10°C.	More & Bhargava, 2010
Influenced on grape composition, wine production and quality for Bordeaux, France.	Jones *et al.,* 2011
apple and pear tree full bloom dates advancement in the southwestern Cape, South Africa.	Grab & Craparo, 2011
Physiological basis of growth and fruit yield characteristics of tropical and sub-tropical fruits to temperature. In: Sthapit BR, Ramanatha Rao V, Sthapit SS (eds) Tropical fruit tree species and climate change.	Dinesh & Reddy, 2012
Reviewed the pollen, ovule characters and fruit set of fruit crops in relation to temperature and genotype	Irenaeus *et al.,* 2014

CHERRIES BIO INDICATOR / THE SUGGESTIONS TO INCREASE YIELD IN FUTURE

Plants are bioindicators of global climate change. The climate events in the Shanghai area due to late frost, chilling, heat waves and drought directly or indirectly effect on the urban forests and trees (Liu *et al.,* 2021). Agriculture is considered the backbone of most of the countries. There are many challenges facing agriculture sector, like climate change (Abobatta, 2018). Crop land cover area is decreasing since last couple of decade rapidly and expected to further decrease due to different types of biotic and biotic stresses more in developing countries as compared to advanced countries which can be overcome with the use of new technologies. For instance, the use of nanotechnology by farmers in richer countries are efficiently utilizing natural resources and getting more agricultural products than poor countries in the agro food sector (Baruah and Dutta, 2009; Dasgupta *et al.,* 2015; Peters *et al.,* 2016).

The adaptation of plant to climate change and immediate environment is necessary. The review of literature also showed that climate change affected the growth, development and production of cherries at global scale and particularly more in under developed countries. It is suggested to note the source of irrigation and analysis of water, soil quality for its nutrients supply before its application to cherries field.

CONCLUSION

The accumulated scientific evidences cited from the different research articles published in various scientific journals concluded that the cherry has a very promising properties on the nutritional, pharmaceutical, ecological and production values. However, recent trend in climatic activities due to increase in temperature affected the cultivation of cherries around the world. The developed countries are using green technology to increase the cherries crop production. Similarly, the adoption of green technology to increase cherries production by developing countries might be helpful in lessening the burden of climate change issues. It is imperative that these gathered information will be helpful for researcher, farmers, working to increase the cultivable area according to the demand and benefits of public to agriculture, horticulture sectors. However, there are many paths of research studies yet needed to be explored, which should allow to further spread the knowledge among governmental, nongovernmental organization and ecologist for its ecological suitability in current scenario of rapid changes in climatic conditions. The training and education of farmers to adopt new green technologies, arrangement of workshop, NGOs will bring promising prospects within the cherry sector. The findings on the cause of decrease in cherries production might be helpful to ecologist, mass media and NGOs are working to increase the cultivable areas of cherries and how to favorably improve the climatic conditions. The data on the physiology, phenology, growth, yield and quality of cherries crops required to be published periodically in print and social media for the awareness among masses to understand its impact.

Author Contributions

Muhammad Shafiq, Muhammad Zafar Iqbal, and Mohammad Athar Tariq composed the review paper with equally participation.

Conflicts of Interest

The authors declare no conflict of interest.

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