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Impact of Climate Change on Growth Performance, Agro-Farming, and Economic Viability of Cherry Cultivation

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ABSTRACT

Climate change is a pressing global concern, significantly impacting agricultural productivity and posing serious threats to plant growth and fruit quality. In Pakistan and many other regions, rising atmospheric temperatures are making climatic conditions increasingly vulnerable, adversely affecting the cultivation and yield of various crops, including cherries. Cherries (*Prunus avium* L.), known for their sweetness, vibrant skin color, flavor, and health-promoting bioactive compounds, hold substantial economic and nutritional value both regionally and internationally. However, cherry production is declining due to factors such as rising temperatures, limited technical resources, low economic capacity, and environmental stresses, particularly affecting growers in developing countries. This review compiles and analyzes scientific literature on the impact of climate change on cherry growth, cultivation, and yield. Relevant data were gathered from English-language sources in databases such as Liebert Pub, CABI Digital Library, PubMed, Google, Google Scholar, and ScienceDirect, covering publications from 1952 to 2025. The findings aim to support farmers, researchers, horticulturists, land managers, media, and NGOs in developing adaptive strategies to sustain and improve cherry production under changing climatic conditions.

KEYWORDS

Bioactive compounds, cultivar, ecotoxicology, global warming, nanotechnology, phenolic, pollution, soil quality, sweet cherry, tart cherry

INTRODUCTION

Cherries as fruit trees with two types, such as sweet cherry and tart cherry, are popular in temperate regions of the world (Fig. 1a-b). There are also different types of varieties of cherries cultivated in temperate and subtropical environments around the world. Dzhuvinov and Kolev[1] recorded nine sweet cherry cultivars-'Nalina', 'B. Burlat', 'Summit', 'Sunburst', 'Lapins', 'Kordia', 'Regina', 'Katalin', and 'Hudson' on Gisela 5 rootstock were planted and the control was 'B. Burlat' on *P. mahaleb*. The cherries are considered to be a good source of all the essential nutrients, being particularly rich in minerals, phenolic compounds, vitamins, sugars, carotenoids, and organic acids, and with traditional medicine with many beneficial properties to humans[2]. Sweet cherries are primarily grown for fresh consumption, but tart cherries are almost entirely processed, that is, dried, canned, juiced, or frozen[3]. Cherries are popularly with

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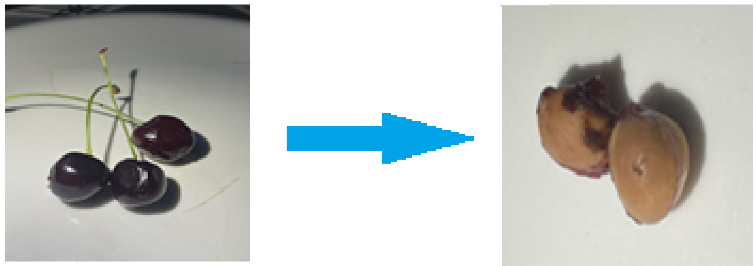

Fig. 1(a-b): (a) Cherry fruit and (b) Seed

the name "Diamond fruit" and are also an excellent source of 52 aromatic compounds, many nutrients, and phytochemicals in addition to contributing to a healthy diet[4-5]. Sweet cherry is a stone non-climacteric fruit with a characteristic aroma, bright red color, and full-bodied taste, and in 2020, a total of 2.6 million tons were produced worldwide[6].

Climate change is responsible for increasing the temperature, heat waves, sea levels, and changes in precipitation, and ultimately, these factors are responsible for influencing plant growth. More severe storms, increased drought, loss of species, and more health risks lead to poverty and the displacement of flora and fauna of the disturbed region/ecosystems. A better agricultural management, conservation, reliance on fossil fuel, and industrial solutions are required to save the cherries growth. The loss in color, flavor of cherry fruit, and potential risk of pesticides to food safety was assessed[7-8].

Researchers around the world is working to examine the impact of climatic disturbances on cherry growth. Among those, Japan contributed valuable insights into understanding these changes through long-term records of the timing of cherry blossoms and other phenomena of ecological, cultural interest[9]. Climate change is a threat to agricultural development, energy, ecosystem processes, natural resources, marine biota, because of the increase of atmospheric CO_2, external temperature, ocean warming, rise in sea level, soil fertility, acidification, and decreased carbonate saturation[10]. Furthermore, environmental stress, heat, and drought are key drivers in food security and strongly impact crop productivity[11]. Poor germination and seedling growth can lead to significant economic losses for farmers[12]. In agriculture, low temperatures limit the yield of crops, while plants can regulate the adverse effects of temperature changes; this ability is limited by various factors, especially in extreme weather[13].

The impact of climate change to variation in fruit production, yield of different fruit crops Cox's Orange Pippin apple in England, 'Hass' avocado fruit, quality of citrus fruit, antioxidant capacity in strawberry, flower development and fruit set in apricot, apple production, Himachal Pradesh (India), quality characteristics of 'Pink' wax apple fruit discs, Physiological disorder in Litchi, pest status of rice and fruit bugs (Heteroptera) in Japan, dormancy in apricot flower buds in two Mediterranean areas: Murcia (Spain) and Tuscany (Italy), cracking and sunburn in litchi, adapting capabilities of grapevine varieties, Litchi and longan, Grape composition, Wine production and quality for Bordeaux, France, Apple and pear tree full bloom dates advancement in the Southwestern Cape, South Africa, Grapevine phenology trends in the Veneto region of Italy for 1964-2009 and Strawberry yield efficiency in Queensland was reported by different researchers[14-32].

In recent years, many studies have been carried out on cherry growth and development performance under the present changing climatic conditions. Studies from throughout the world have provided evidence that climate change has badly affected the ecosystem and ecology of species. This review was aimed to provide relevant, meaningful, and up-to-date information on cherry 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, businesses, commercialization, and professionals working in agriculture and food sectors, and this review covered the scientific literature published from 1952 to 2025.

REVIEW DATA COLLECTION

The growth and development performance parameters of cherry around the world in changing climatic conditions were searched from the research articles published globally in different scientific English databases, such as Liebert pub, CABI digital library, PubMed, Google, Google Scholar, and Science Direct, covering the period from 1952 to 2024. The AMA reference citation style was used. The keywords include 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 the English language were analyzed, and of them, 118 research articles were finally selected for review and included in the reference list.

CLIMATE CHANGE AND POLLUTION

Climate change, environmental pollution, soil quality due to automobiles, industrialization, high rate of population growth, urbanization, and anthropogenic activities drastically damage crop productivity in developing countries, likewise, in Pakistan on an alarming scale. Table 1 shows the effect of climate change on sweet cherry trees at the regional and global levels.

Climate change and the growing world population are main challenges leading to agriculture and food safety issues[51-52]. Due to the rapidly changing climate, declining soil fertility, a lack of macro and micronutrients, and improper use of different agrochemicals, the agricultural sector is currently experiencing a severe crisis[53].

There are different types of strategies available to improve the production of cherries. The application of nanotechnology has emerged to help in safeguarding the many global food security issues and the impacts of climate change[54]. There has been an increasing demand for food resources over the last few years due to rapid population growth. The use of nanoparticles and the future of nanofertilizers in sustainable agriculture was well documented by Basavegowda *et al*.[55] and Finchira *et al*.[56]. 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[57-61]. Figure 2 shows the influence of climate change on the soil and aerial parts of the cherries.

The world faces formidable, but manageable, challenges in achieving food security in a world growing beyond 9 billion people in the coming decades[62, 63]. Acute water deficit conditions, soil salinity, and high temperature have been on the rise in their magnitude and frequency, which have been found to impact plant growth and development negatively due to the consequences of global climate change[64]. Climate change imposes various environmental stresses that substantially impact plant growth and productivity. Many interesting strategies are being researched in the attempt to improve plants environmental stress tolerance in plants[65]. The agro farming industry is facing many environmental challenges to human civilization[66]. An increase of food consumption demand is expected between 58-98% for the world population, which is predicted to reach 11 billion in 2100[67]. Therefore, an innovative and sustainable solutions approach to meet the growing need for food worldwide is required[68].

BOTANICAL DESCRIPTION

The demand for more cherry production in recent years is increasing due to high public demand and population growth. Table 2 describes the botanical features of cherry (*Prunus avium* (L.) Moench).

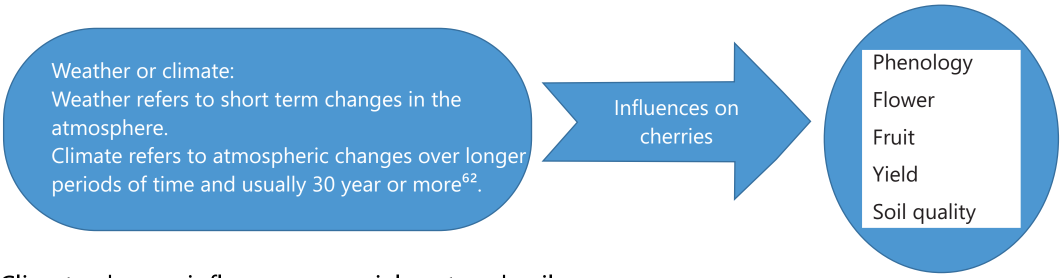

Fig. 2: Climate change influence on aerial part and soil

Table 1: Impact of climate change variability on sweet cherry tree

Climate change action	References
Global warming influenced a group of related species and their hybrids: Cherry tree (Rosaceae) flowering at Mt. Takao, Japan	Miller-Rushing *et al.*[33]
Polyphenolic Compounds in sweet cherries with main focus on Anthocyanins, *Mechanisms of Action in Human Health and Disease*	Kent *et al.*[34]
Agroecological conditions are affected due to the increasing risk of spring frost occurrence during flowering times. The positive trend of frost-day occurrence and the negative trend of minimum air temperature in cherry tree flowering indicated that blossoms were more in endangered condition at higher elevations in the Czech Republic (Central Europe) from 1924-2012, 1924-1967, and 1968-2012	Hájková *et al.*[35]
Climate change and spring frost are limiting factors for damage of sweet cherries flower production in NE (Berlin) and SW Germany (Geisenheim), Germany. Rising temperature also forces the development of buds in spring	Chmielewski *et al.*[36]
The flower parts (sepal, pedicel, receptacle, petal, stamen, and pistil) of the sweet cherry in sub-zero temperatures found sensitive to sub-zero temperatures. Unpredictable late spring frost is a major cause of risk to sweet cherry.	Kaya and Kose[37]
Sweet cherry was reported sensitive to reduced chill accumulation (Fewer chilling hours in winter) and to late frost damage caused by flower opening time advancement. The fruit growing in Southern Europe was found sensitive to climate change when compared to long-term records of both phenological (Flowering) data and weather (Frost, temperature) at both locations indicated the opposite. Sweet cherry production in the colder climate at Menckenian showed greater lowering is more susceptible to frost, making it less resilient to climate change.	Drogoudi *et al.*[38]
Cherry growers perceived adaptation efficacy to climate change and meteorological hazards in Northwest China. An appropriate climate for cherry growth is important, and in terms of temperature, different growth stages from germination and anthesis to young fruit growth have different temperature requirements	Song and Shi[39]
Impacts of climate change on the transcriptional dynamics and timing of bud dormancy release in the Yoshino-cherry tree. The iconic Yoshino cherry tree in Japan is experiencing shifts in its blossom timing due to climate change. This study demonstrated that seasonal gene expression profiles serve as a valuable indicator for forecasting the timing of dormancy release, benefiting Japanese traditions and providing insights into the biological impacts of climate change.	Miyawaki-Kuwakado *et al.*[40]
Impact of global warming on the flowering of cherry trees (*Prunus yedoensis*) in Japan due to dual requirements of chilling and heat during dormancy release renders the process intricate. The current global warming trend may induce a delay in endodormancy release but an earlier ecodormancy release, potentially resulting in varying flowering patterns, either advancing, delaying, or even potentially inhibiting flowering altogether, depending on the seasonal temperature profiles. Process-based models have predicted that the Yoshino cherry trees will not bloom in the Southern regions of the country around the year 2,100, a region which marks the southernmost boundary of their Flowering	Maruoka and Itoh[41]
Phenological data series of cherry tree flowering in Kyoto, Japan, and its application to the reconstruction of springtime temperatures since the 9th century. Changes in springtime temperature in Kyoto, Japan, since the 9th century were reconstructed using the phenological data series for cherry tree (*Prunus jamasakura*), deduced from old diaries and chronicles. Phenological data for 732 years were made available by combining data from previous studies. The full-flowering date of cherry trees fluctuates by temperature conditions during February and March,	Aono and Kazui[42]

Table 1: Countinue

Climate change action	References
Nomenclature of Tokyo cherry (*Cerasus*×*yedoensis* 'Somei-Yoshino', Rosaceae) and allied interspecific hybrids based on recent advances in population genetics explained. The flowering cherries, *Cerasus* (*Prunus* subg. *Cerasus*; Rosaceae), including *C.*×*yedoensis* 'Somei Yoshino', are popular ornamental trees in temperate regions of the world. Recent advances in molecular and population genetics have revealed that this group originated as an interspecific hybrid. A new nothospecies, *C.*×*kashioensis* is proposed for a hybrid between *C. itosakura* and *C. leveilleana*.	Katsuki and Iketani[43]
Cultural ecosystem services provided by the flowering of cherry trees under climate change: A case study of the relationship between the periods of flowering and festivals. In Japan, cherry blossoms are an important tourism resource and provide many cultural ecosystem service benefits. Under future warming conditions, such as changing the timing of flower festivals to account for changes in the flowering phenology, was discussed. The coincidence between the flowering phenology of cherry blossoms and the associated festival periods in two Japanese cities under past, recent, and future climate conditions. Thus, moderate warming may increase the value of cherry blossoms to the tourism industry. Under more than 3.5°C warming in Shinhidaka and 2.5°C warming in Takayama, however, cherry blossoms will have already dropped by Golden Week and the spring festival period, respectively, suggesting that greater warming may decrease the value of this tourism resource.	Nagai *et al.*[44]
Phased genome sequence of an interspecific hybrid flowering cherry, 'Somei-Yoshino' (*Cerasus*×*yedoensis*). The phased genome sequence of an interspecific hybrid, the flowering cherry 'Somei-Yoshino' (*Cerasus*×*yedoensis*) for the sequence data were obtained by single-molecule real-time sequencing technology, split into two subsets based on genome information of the two probable ancestors, and assembled to obtain two haplotype phased genome sequences of the interspecific hybrid. These genome and transcriptome data are expected to provide insights into the evolution and cultivation of the flowering cherry and the molecular mechanism underlying flowering	Shirasawa[45]
Cherry blossom forecast based on transcriptome of floral organs approaching blooming in the flowering cherry (*Cerasus*×*yedoensis*) cultivar 'Somei-Yoshino'. To gain insights into the genetic mechanisms underlying blooming and petal movement in the flowering cherry (*Cerasus*×*yedoensis*)	Shirasawa[46]
The origin of the Yoshino cherry tree and data on the morphological characteristics were presented for the ornamental *Prunus yedoensis*, for its putative parents, and certain seedlings and hybrids. These suggest that *P. yedoensis* may be a hybrid between *P. speciosa* and *P. ascendens* and that it may have originated in the Izu peninsula, where these species grow. National Institute of Genetics, Mishima, Shizuoka-Ken, Japan	Takenaka[47]
From bud formation to flowering stage is a crucial stage and allows survival over winter to ensure optimal flowering and fruit production. Recent work highlighted physiological and molecular events occurring during bud dormancy in trees. The authors further explored the global transcriptional changes happening throughout bud development and dormancy onset, progression, and release. Such integrative approaches will therefore be extremely useful for a better comprehension of complex phenological processes	Vimont *et al.*[48]
Climate change affects the suitability of Chinese cherry (*Prunus pseudocerasus* Lindl.) in China. The rapid development of the *Prunus pseudocerasus-related* industry has increasingly contributed to rural vitalization in China. This study employed a biomod2 ensemble model, utilizing environmental and species occurrence data from 151 *P. pseudocerasus* germplasm wild/local samples, to predict potential geographical distribution, suitability changes, climate dependence, and ecological niche dynamics. The climate variables with the greatest impact on suitability were precipitation of the warmest quarter and mean diurnal temperature range. Climate change is driving both the expansion of geographical distribution and the contraction of overlapping geographical distribution areas of *P. pseudocerasus*	Lv *et al.*[49]
Climate change impacts on fruit farm operations in Chile and Tunisia, with farmer insights into how climate change impacts cherry and peach farmers in Chile and Tunisia regarding climatic effects on their farm operations. The approach offered a unique, farmer-driven perspective on climate-related issues. The results reveal a nuanced picture: Climate change is a major concern for cherry farmers in Chile, whereas financial and social issues are more pressing for peach farmers in Tunisia	Pechan *et al.*[50]

Table 2: Botanical description of cherry (*Prunus avium* L.) Moench

Parameter	Description
Domain	Eukaryote
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, Durone Nera, Early Star, Ferrovia, Gabbaladri, Genovese, Giorgia, Grace Star, Maiolina Grappolo, Maredda, Minnulara, Moreau, Napoleona Forestiera, Napoleona Grappolo, Napoleona, 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, without suckers from the roots, deciduous, unarmed. Bark reddish brown to blackish, splitting horizontally. Perulate winter buds ovoid-ellipsoid, glabrous. Branchlets glabrous, green when young, becoming red-brown and shiny
Leaves	Leaf blade ovate to obovate or oblong, 3-16×2-8 cm, base cuneate to rounded, apex acute to acuminate or mucronate, margin irregularly serrate or biserrate with glandular teeth, adaxially glabrous, abaxially usually densely pilose when young becoming glabrous or pilose along the nerves or with tufts of hairs in the axils of the nerves and midvein. Petiole 1-7 cm long, usually with 2-3 glands towards the apex, glabrous. Stipules linear, ca. 1 cm long with glandular serrate margin, caducous
Flower	Flowers 1.5-3 cm in diameter, in fascicles of 2-5, opening with the leaves. Pedicels 2-6 cm long, glabrous. Bracts scarious (not leafy), the inner recurved, caducous. Hypanthium urceolate, 5 mm long, glabrous. Sepals ca. 5×3 mm, oblong to ovate, obtuse at apex, usually entire, reflexed. Petals white, obovate, ca. 12×7 mm, apex emarginate. 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, sub globose, ca. 1 cm in diameter; mesocarp fleshy and juicy, sweet to bitter; endocarp globose to ovoid, smooth, 6 mm across
Bioactive compounds	Glucose, malic acid, rich in minerals, phenolic compounds, vitamins, sugars, carotenoids, and organic acids. phenolic extract demonstrates a high concentration of both in phenolic acids, mainly hydroxycinnamic acids and in anthocyanin's with cyanidin 3-O-rutinoside being dominant, while its by-products are characterized by a higher total phenolic content. The total soluble solids (TSS), total acidity (TA), weight loss, respiration rate, firmness, color, phenolic contents, and sensory attributes to enhance the shelf life of sweet cherries
Pharmaceutical properties	It is characterized by its strong antioxidant, antimicrobial, anti-diabetic, and anti-cancer effects. In folk medicines, the fruits and other parts of the *Cornus mas* L. (cornelian cherry) have been used for centuries as traditional cuisine and folk medicine in various countries of Europe and Asia for prevention 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, which affects the fruit quality and aroma compounds of the cherry during cold storage. Alternaria alternata, black spot.
Miscellaneous uses	Edible fruit (sweet cherry), seed kernel oil, and wood used for furniture making

Reference source:[69-73]

HISTORY AND ECONOMIC IMPORTANCE

Cherries have a long history to ancient times with significant cultural and economic importance across the globe and regional level, including Pakistan. Turkey, USA, Iran, Uzbekistan, Chile, Italy, and Russia are major cherry producing countries, and in developing countries, cherry yield is 4 ton/acre, while in advanced countries it is 12 ton/acre due to high-density plantation[74]. Cherry fruits proved with high content of phenolic compounds, as functional foods and containing the full biological potential[75].

IMPACT OF CLIMATE CHANGE ON PHENOLOGICAL CHARACTERISTICS

Phenology is dominated by different ecological factors, commonly published in the scientific literature. In some Asian countries (Japan, Korea, and China), the phenology for flowering dates of cherry blossoms was affected due to fluctuation in air temperature, coldness/warmth indices in the month of March[76]. The mean flowering dates of cherry blossoms in Japan and Korea became 3-4 days earlier when the mean air temperature of March increased by 1°C. The first flowering and full blossom days of Yoshino cherry trees were observed from 82 stations after 68 years from 1953 to 2020 in Japan[77]. It is expected that in the Northern Hemisphere, the intensity of climate extremes may influence the plant phenology and its phenophases as a result of global warming in Burlal cherry[78]. In another study, the opening of flowering date and full bloom were affected due to warmer spring temperature as well as late frost throughout Europe based on 30 years of phenological data, including calendar[79].

The changes in phenological timings of leaf budburst of cherries with climate change were recorded in urban cities of Japan[80]. The other reason might be due to the increase in energy consumption, that usually responsible for environmental problems in urban sites of the cities. The future prediction of the urban heat island in the metropolitan area of Tokyo using three-dimensional computer simulation showed the energy release rate five times as much as the present rate, which corresponds to the year 2031, and suggested that if the present consumption rate is maintained until then[81]. The potential for contemporary data to record flowering patterns was studied in Japan, where cherry (Sakura) flower viewing Hanami, within an ecology framework, by collecting images from the SNS Flickr over the decade 2008-2018 of decade[82].

IMPACT ON VEGETATIVE GROWTH AND YIELD PRODUCTION

The yield of cherries may be threatened in warmer growing regions by insufficient dormancy, which usually occurs in late-blooming genotypes. Whereas, conversely, in cold regions, the yield was threatened by late spring frosts, especially for early-flowering cultivars[83]. In addition, in a temperate climatic zone, its production may be hampered immediately at the beginning of a growing season when the number of flowers per tree was recorded by the same authors as significantly reduced or blooming trees are damaged by late spring frosts. A cold period in winter (chilling) with a subsequent warm period (forcing) for flowering in many horticultural crops, such as apple, pear, plum, cherry, strawberry, and Asparagus, are required[84]. The different chilling treatment in four consecutive winters at Klein Altendorf, near Bonn (50°N), Germany for 160 potted sweet cherry trees were exposed with a wide range of chilling requirement (3-fold) in eight scenarios per variety per year, ranging from 50% less/insufficient chill for warm temperature zone winters to +50% more or excess chill for cold winter fruit growing regions. The authors concluded that the effects of climate change using cherry were the most affected crop. In another research study, a linear rise in temperature from 24 locations around the world, from the three sites – two in India (Bagalkot and Uttar Pradesh) and one in Argentina, has become an important issue of climate change and recorded the main reason for reduced banana growth[85].

CLIMATE CHANGE ALTERED THE FRUIT QUALITY

The biotic and abiotic factors, such as extreme temperatures, light radiation, and nutritional conditions, significantly influence the physiological, biochemical, and molecular processes associated with the quality of edible fruit and living organisms under stressful conditions[86]. The development and ripening process of sweet cherry (*Prunus avium* L. cv 4-70) on the tree was evaluated[87]. The results of the investigation showed that the changes in skin color, glucose and fructose accumulation, and softening process of cherry were initiated at early developmental stages, and also a decrease in color parameter due to the greatest accumulation of total anthocyanins. Temperature regulates differently the physiological and biochemical functions of the plants. The climate changes are responsible for fruit quality, fruit set, reduction in fruit size, low juice content, lower yield, and higher risk of pest attack, proper pigmentation, disease, and distribution significantly on fruit crops[88-89]. The higher antioxidant activity in 'Kent' strawberries under warm days (25°C) and warm nights (18-22°C) and earlier ripening by the end of this century in California, which may result in lower quality of grapes in the region[90-91]. Sweet cherry is a non-climacteric stone fruit of the genus *Prunus* and has a good return for grower[92]. Climate change is an emerging threat to global food, nutritional security, and tropical fruits are suggested to be highly sensitive to weather changes, especially changes in monsoon onset and elevated temperature, are influence crop growth and production[93]. Whereas, an increase in temperature affected the edible parts such as fruit, leaf, and root[94].

CLIMATE CHANGE AND POLLEN DEVELOPMENT

Plants are finely tuned to the seasonality of their environment, and shifts in the timing of plant activity (phenology) provide some of the most compelling evidence that species and ecosystems are being influenced by global environmental change[95]. Temperature stress seriously affects the disruption of pollination activity, which accounts for 35% of the world's food production[96]. Plant-pollinator interactions get disturbed due to temporal (phenological) and spatial (distributional) mismatches. Temporal changes are already visible as *Apis mellifera* accelerated their activity period earlier than their preferred forage species' flowering peaks, and spatial shifting of areas in impoverished countries[97]. Crop plants that are self-incompatible, pollinator-limited, and pollinator-specific are more vulnerable to this threat. Rising temperatures can hasten plant growth and development. High temperature stress has shown an alarming threat to the global food system. However, furthermore, some agronomic and breeding approaches have been adopted for developing thermo-resistant cultivars of rice for the morpho-physiological and molecular response[98].

CLIMATE CHANGE AND FLOWERING

The production and productivity of flowering of different plant species are affected by climate change. An overview of the impacts of anthropogenic activities and climate change resulting from increasing concentration of carbon dioxide on the environment in the 21st Century was evaluated[99-100].

Insufficient chilling requirements during warm seasons cause some phenological disturbances, including late flowering, prolonged flowering times, and a longer time between flowering and harvest in apple[101]. In the pastoral landscapes of Chile, two farming ventures faced increasing challenges from unpredictable weather, water scarcity, and rising temperatures[102]. The rise of global temperatures affected plant phenology, and spring warming can lead to early flowering due to accelerated heat accumulation after dormancy. Hsu *et al*.[103] 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). The analysis of data showed that the effects of chilling temperatures during dormancy were variable along the latitudinal gradient, while the effect of forcing temperatures after dormancy was more consistent regardless of latitude.

IMPACT ON PEST AND DISEASE INCIDENCE

The occurrence of pests and diseases in fruit crops can result from the introduction of new pests and the breakdown of resistance due to climate change. The Sigatoka disease has occurred in destructive proportions in Maharashtra (India) in stone fruits[104-105]. The life cycle of various insect pests could lead to changes in geographic distribution, population growth rates, crop-pest phenology synchrony, and increased risk of invasion by migrating pests, and interspecific interactions due to climate change[106]. The development of the fruit fly in Mango Cv Chausa increased due to the temperature rising from 20 to 35°C[107].

FUTURE CHALLENGES AND SOLUTIONS

Trees are considered bioindicators of global climate change. Jaeger *et al*.[108] compared accelerometer-estimated phenophases. The guidance for future-oriented urban forest management and tree species selection in Shanghai on climate events, such as late frost, heat waves, drought, soil salinization, pests, and disease, directly or indirectly impact was presented[109].

Agriculture is considered the backbone of most countries. There are many challenges facing the agriculture sector, like climate change, unreasonable use of resources, and the use of too much chemical fertilizer[110]. Crop land cover area has been decreasing over the last couple of decades and is expected to further decrease due to different types of biotic and abiotic stresses 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 is efficiently utilizing natural resources and getting more agricultural products than poor countries in the agro-food sector[110-113]. The ecological, ethnobotanical, economical, beneficial, biological, nutritional, and pharmaceutical potential of different plant species, namely *Alhagi maurorum* Medikus, Olive tree *Olea europaea* L., *Albizia lebbeck* (L.) Benth, and *Calotropis procera* (Aiton) R. Br. rubber bush (Apple of Sodom), widely grown in a desert environment, was reviewed[114-116]. Additionally, if this rise in climate change conditions is not controlled, then the adaptation will not be sufficient.

The review of literature also showed that climate change affected the growth, development, and production of cherries a global scale, particularly in developing countries. It is suggested to note the source of irrigation and analysis of water, and soil quality for its nutrient supply before its application to the cherry field.

CONCLUSION

The compiled scientific evidence highlights the significant nutritional, pharmaceutical, ecological, and economic potential of cherry cultivation. However, rising global temperatures have adversely impacted cherry production, particularly in regions lacking adaptive strategies. The adoption of green technologies in developed countries has shown positive outcomes, suggesting that similar practices in developing nations could mitigate climate-related challenges. To support sustainable cherry cultivation, it is essential to educate and train farmers, organize awareness workshops, and engage NGOs in promoting innovative agricultural practices. Further research is needed to explore ecological suitability under changing climatic conditions. Regular dissemination of findings on cherry physiology, growth, yield, and quality through print and social media can enhance public and institutional awareness, ultimately contributing to improved cherry production and expanded cultivation areas.

SIGNIFICANCE STATEMENT

This study identified the impacts of climate change on cherry cultivation in Pakistan, focusing on how urbanization, industrialization, and rising global temperatures affect the growth and yield of this important economic fruit crop. The findings highlight the potential benefits of adopting advanced technologies such as nanotechnology, nano-materials, and biotechnology to improve cultivation practices and production. This study will assist researchers in uncovering critical areas of climate-resilient agricultural practices for cherry cultivation that have remained unexplored by many. Consequently, a new theory on climate-smart agricultural interventions for cherry farming may be developed.

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