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19. Impact of Climate Change on Floriculture

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Abstract:

A growing number of people now acknowledge that one of the biggest threats to humanity and all other life on Earth is climate change. Climate change encompasses a wide range of changes to the climate and their effects at various levels, from local to global. Global climate change has been linked to reported changes in seasonal patterns, weather patterns, temperature ranges, and other related phenomena on a global scale. It is having a discernible impact on the life cycles and distributions of vegetation worldwide. While predicting the future effects of climate change is challenging, current data reveals that it is already influencing various flowering plants, underscoring the urgent need for action to mitigate its consequences.

Keywords:

Climate change, Floriculture, Temperature, CO_2.

19.1 Introduction:

Climate change is one of the most pressing global environmental issues in human history, driven primarily by the increasing levels of greenhouse gases (GHGs) in the atmosphere. Human activities such as burning fossil fuels, deforestation, and industrial processes have led to a significant rise in GHG emissions. The scientific consensus on human-induced climate change began to take shape in the 1980s, and since then, climate change has become widely recognized as a major threat to human societies and all life on Earth. The evidence of climate change is evident in shifting seasonal patterns, extreme weather events and rising temperatures worldwide.

Experts from various scientific disciplines have sounded the alarm, warning that if we fail to address these environmentally harmful activities, the consequences of climate change will only intensify and become more frequent in the future.

There are discernible effects of climate change on the life cycles and global distributions of vegetation. Although the effects of climate change are still largely unknown, evidence from the present indicates that a number of flowering plants are being impacted and that there may be some serious threats that need to be discussed. Numerous tactics are employed to preserve, propagate, enhance, produce, and safeguard priceless ornamental species and varieties. In order to ensure ecological and environmental functionality, many of the new technologies under development adhere to nature-based solutions.

19.2 Climate Change:

Climate change encompasses all changes to the climate and their effects at various levels, from local to global. In recent years, climate change is one of the most significant global environmental challenges, catching attention. Climate changes impact factors like temperature, precipitation and atmospheric greenhouse gas concentration or GHC. All aspects of agriculture, including Floriculture, are impacted by these, either directly or indirectly. A few of the issues with the direct impact are seen in the way the plant cycle has changed as a result of rising temperatures, faster crop respiration rates, changes in photosynthesis and evapotranspiration, pest population resistance, soil mineralization, and more effective fertiliser application. Indirect effects of climate change include altered soil erosion and organic matter transformation, increased frequency and severity of pestilential and pathogenic diseases, and increased intensity of droughts and floods.

Particular to the field of floriculture, climate change has the potential to cause flowering failure or alter the blooming period, as well as reduce flower size and cause abnormal colour development, especially in open fields. Increased temperatures can directly affect the evaporation of volatile fragrances and the degradation of pigments in flowers. A decrease in post-harvest life and inadequate pollination reflection on seed production were two additional factors that had already been noted.

19.3 Impact of Climate Change on Floriculture:

The art and science of growing flowers and decorative plants is known as floriculture, and it is a thriving industry that is important for the environment, economy, and aesthetics. However, the unabated advancement of climate change presents this fragile industry with ever-greater challenges. Numerous factors are threatening floriculture's sustainability and productivity as global temperatures rise and weather patterns become more unpredictable. Climate change is a concern for the future of flower cultivation because it will alter growing seasons and increase the pressure from pests and diseases. In order to put adaptive strategies into practice and guarantee floriculture's resilience in the face of this worsening environmental crisis, it is imperative to understand these impacts.

Climate change affects floriculture in several ways, influencing everything from plant growth and development to market dynamics. Here are some key impacts:

19.3.1 Shifts in Growing Seasons:

Changes in precipitation and temperature due to climate change cause changes in the length of the growing season. Plants can extend their growing seasons or bloom earlier as a result of warmer winters and earlier springs. On the other hand, erratic weather phenomena like late frosts can harm crops, lowering their quality and marketability.

19.3.2 Changes in Plant Hardiness Zones:

The geographic locations where particular plants can flourish, known as plant hardiness zones, move northward or upward in response to rising temperatures. Because of this, some species are more profitable to grow in particular areas than others, which forces floriculturists to modify their crop selection and production techniques.

19.3.3 Water Availability and Irrigation Challenges:

Climate change affects floriculture irrigation practices by making water scarcity worse in many areas.

In order to maintain flower production while minimizing water usage, effective water management techniques like drip irrigation and rainwater harvesting are required due to irregular precipitation patterns, extended droughts, and increased evaporation rates.

19.3.4 Pest and Disease Pressure:

Rising temperatures and altered precipitation patterns create favorable conditions for pests and diseases that attack flowers and ornamental plants. Increased pest populations and the spread of plant pathogens pose significant challenges to floriculture, requiring enhanced pest management techniques and the development of resistant plant varieties to mitigate losses.

19.3.5 Extreme Weather Events:

The frequency and intensity of extreme weather events like storms, floods, and heat-waves are increased by climate change, and these events have the potential to destroy infrastructure and flower crops.

In addition to lowering yields, heat stress, flooding, and storm damage can damage supply chains, which can cause market instability and financial losses for floriculture companies.

19.3.6 Impact on Floral Biodiversity:

Climate change threatens floral biodiversity by altering ecosystems and disrupting plant-pollinator interactions. Variations in temperature and precipitation can have an impact on native plant distribution and abundance, which can change the floral composition and diversity of both natural and cultivated landscapes.

19.3.7 Economic and Marketing Effects:

Increased production costs, crop losses, and market volatility are just a few of the cumulative effects of climate change on floriculture that can have a big financial impact on growers, distributors, and retailers. Furthermore, affecting the floriculture industry's profitability and competitiveness are variations in supply and demand as well as shifts in consumer preferences brought about by climatic changes in floral availability and aesthetics.

19.4 Effects of Climate Change on Floriculture:

The changes on climate affect variables such as temperature, rainfall, and atmospheric greenhouse gas concentration – GHC.

19.4.1 Temperature:

Temperature is a primary factor affecting the rate of plant development. It influences most plant processes, including photosynthesis, transpiration, respiration, germination and flowering. As temperature rises (up to a certain threshold), there is an increase in photosynthesis, transpiration, and respiration. Flower development, flower initiation, and flowering time are all regulated by ambient temperature. Crop quality and plant carbon balance are also impacted by temperature. At optimum temperature plant is able to synthesize maximum carbohydrates and have a normal rate of respiration. For example, in pansy orchid (*Zygopetalum Redvale* cv. 'Fire Kiss') the temperature of 14 to 26°C resulted in delay of inflorescence to flower by 43 days. Days to visible bud and anthesis tend to decrease with the increase in temperature from 15 to 26 °C in tick seed (*Coreopsis grandifora*), shasta daisy (*Leucanthemum superbum*), and black-eyed susan (*Rudbeckia fulgida*).

A. Role of Temperature in Flower Initiation:

The photoperiod in which a plant is growing influences the production of both flowering promoters and inhibitors. Once the synthesis of either is triggered by the time-measuring mechanism, the rate of synthesis is likely to be significantly impacted by temperature. In both long-day and short-day plants, higher temperatures during the favourable phase of an inductive photoperiodic treatment typically enhance flower initiation, whereas lower temperatures have an inhibitory effect.

A change in photoperiodism and thermoperiodism would result in a significant alteration in the flowering patterns of plants such as carnations, chrysanthemums, and poinsettias. Due to the direct effects of climate change, small-scale growers who depend on rain-fed floriculture will be particularly vulnerable. The effects of climate change on agriculture and flowering plants are becoming more and more obvious. A shorter blooming season, improper floral growth and colour development, and insufficient flowering are all problems associated with commercial flower cultivation, especially that of open fields. Native species may be threatened by inadequate agroclimatic conditions in their natural habitat, which could also prevent them from spreading.

For plants growing in cooler climates, the response to low temperature is usually considered to be of two types:

- Low temperature initiation:
- Vernalization

Low temperature initiation: Low temperatures lead directly to the initiation of flower primordia while plants are growing in cool conditions.

Vernalization: Vernalization refers specifically to exposing mature plants or their seeds to periods of cold temperatures Vernalization does not directly cause initiation of flowers or inflorescences; it only leads to 'competence' which in turn enables the plant to enter the reproductive phase of development under subsequent warm conditions. Short term exposure to low temperatures leads to vernalization while longer exposure results in low temperature initiation.

Table 19.1: Temperature for Flowering of Commercial Flower Crops

Flower crop	Flowering temperature	Flower crop	Flowering temperature
Alstroemeria	13-25 ºC	Gladiolus	25 ºC
Anthurium	24-28 ºC	Jasmine	15-24 ºC
Carnation	15-35 ºC	Lilium	18-22 ºC
Chrysanthemum	10-27 ºC	Marigold	18-20 ºC
Crossandra	30-35 ºC	Orchids	24 ºC
Dahlia	20-22 ºC	Rose	15-24 ºC
Gerbera	21 ºC	Tuberose	27 ºC

19.4.2 Light:

Light plays a vital role in controlling the metabolism of carbon in plants and maintaining their physiology throughout their life cycle. It provides photosynthesis with energy and acts as a signal for different growth processes. Light triggers the emergence of chloroplasts, seedling growth, and the breaking of dormancy in seeds. For photosynthesis, plants use wavelengths between 400 and 700 nm, with red light (600–700 nm) being absorbed most effectively. While carotenoids absorb blue light (448–452 nm), chlorophyll-a and chlorophyll-b peak at 430 and 665 nm and 453 and 642 nm, respectively. By absorbing too much radiation, anthocyanins provide protection against photoinhibition.

A. Light Duration:

The 24-hour cycle of light and dark that plants experience is known as their photoperiod. It may also refer to a plant's ability to alter its behavior in response to the duration of the day or night. Numerous plant developmental responses, including flowering, are regulated by photoperiod. Substratum and enzyme activity, which are present all day, cause these reactions, and light converts these enzymes from an inactive to an active state.

Additionally, it significantly affects pubescence, pigment formation, abscission, leaf shape, and root development.

Classification of plants based on photo period requirements:

a. short day plants: When dark periods exceed a critical duration, flowering is accelerated.

b. Long-day plants: When a plant has a long day (LD) and experiences less than a certain critical duration of darkness, flowering is encouraged.

c. Day-neutral plants: photoperiod has no effect on flowering

Mature leaves, which generate metabolites that cause flowers and are transported through the phloem to the apex, allow plants to detect the photoperiod. Depending on the type of plant, the minimum number of cycles required to initiate the flowering response can range from one day to several weeks. Nevertheless, once the flowering stimulus is detected, the apical meristem is identified, and plants can blossom in a variety of environmental circumstances.

B. Effect of Light Intensity:

Leaf morphology and anatomy are governed by shade. Regarded as the primary organ for photosynthesis and transpiration in plants, leaves' structure reveals how environmental conditions affect plants or how they adjust to their ever-changing surroundings.

In a leaf under normal light, the thickness and photosynthetic capacity are strengthened by the elongation and expansion of the palisade tissue, which increases the area of the chloroplast channel through which CO_2 enters. However, smaller leaf area and thinner leaves are the result of shade or low PAR irradiances; this is a common adaptation mechanism found in many plant species. Because thinner leaves have less dry mass per unit area and because of their structural features, which increase light reflection and scattering in the leaves and help plants maximise light penetration into the leaves to increase light absorption for chloroplasts under low light conditions, most scientists believe that thinner leaves have a greater ability to intercept light. Its structure does not facilitate the transportation and dissolution of CO_2, though, because thinner leaves have less chloroplast and thinner palisade tissue than thicker leaves. Therefore, photosynthesis and biomass accumulation are not effectively performed by thinner leaves. Furthermore, plants growing in shadow devote more biomass to growing stems at the expense of growing leaves. When considered collectively, these results point to a reduced PAR-induced growth inhibition of plant leaves.

C. Light Quality:

The blue and red regions of the spectrum are the most beneficial for photosynthesis. Red light influences the development of the photosynthetic apparatus, and red and blue light are most effectively used for photosynthesis. Plant height, stomatal opening, and chlorophyll biosynthesis are all influenced by blue light, whereas long-day plants are stimulated to flower by far-red light. The red/far red ratio governs the growth of leaves, reproduction, and stem elongation and branching in higher plants. The three main pigments that absorb light are carotenoids, anthocyanins, and chlorophylls.

Plant photoreceptors are light-sensitive molecules that can control flowering, as demonstrated by a light-sensitive pigment and a protein. Phytochromes, or red/far-red light receptors, are the primary photoreceptors involved in flowering regulation. Phytochromes, which exist in two interconvertible forms, Pr and Pfr are proteins that give plants that detect red/far-red light their photoperiod sensitivity. The inactive form of phytochrome, or Pr, has two absorption peaks: a primary peak at 660 nm (red) and a secondary peak at about 380 nm (UV-A). Pfr, is the active form of phytochrome with an absorption peak at 730 nm (far-red wavelengths) and a smaller peak at 408 nm (blue wavelengths). Pfr accumulation can inhibit flowering in short-day plants and have the exact opposite effect (Flower induction) in long-day plants. Pfr transforms into Pr form during the dark period. For this reason, extended periods of darkness encourage flowering in plants with short days. Pr will change back into Pfr form if we expose it to red light for a short while during a dark period.

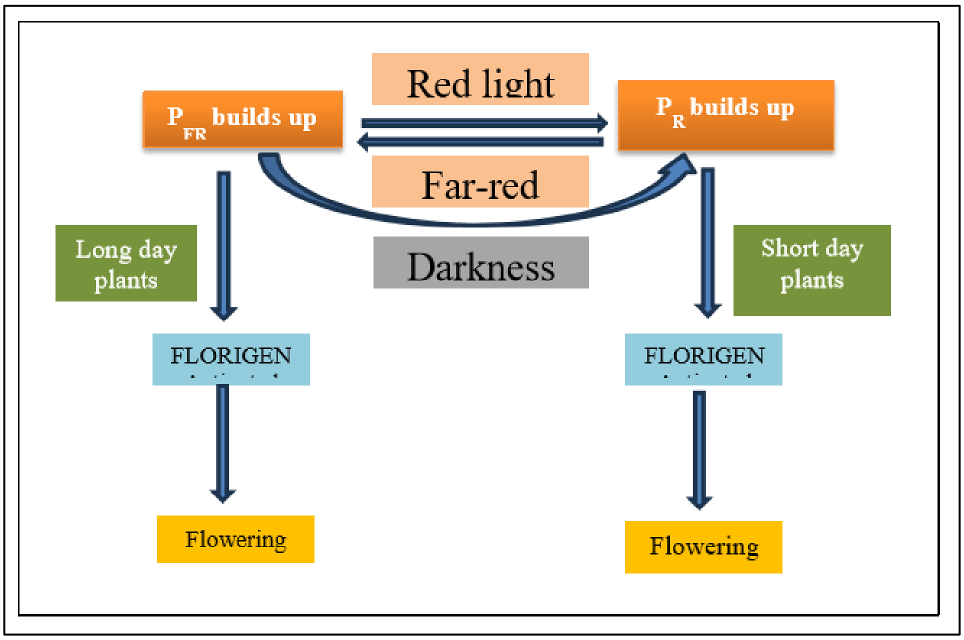

Figure 19.1: Light Quality

Light has both qualitative and quantitative effects on growth and development.

a. The qualitative aspects include the importance of critical day length and spectral quality.
b. The quantitative aspects include an increased response with fluence rate.

Spectral quality has a major influence on the rate of flower bud induction and subsequent development. Light source had a significant effect on the number of flower buds and open flowers.

Table 19.2. Light requirement for some of the flowering crops.

Flower crop	Light requirement (Lux)
Monopodial orchids	25000
Sympodial orchids	40000-45000
Chrysanthemum	22000-27000
Carnation	21500
Alstromeria	3000-3500
Gerbera	3500-4000

19.4.3 Relative Humidity (RH):

Relative humidity is the precise proportion of moisture in the atmosphere. Relative humidity (RH) affects a plant's water relations directly and indirectly through effects on photosynthesis, pollination, leaf growth, disease incidence, and ultimately economic yield. controls the opening of the stomata during photosynthesis.

The development of turgor pressure inside the cells leads to cell enlargement. Less transpiration results in a high turgor pressure under RH. Thus, humid environments have higher leaf enlargement rates. RH has an indirect effect on photosynthesis. Low RH causes increased transpiration, which leaves the plant with water deficits.

A crucial factor in crop production is the relative humidity of the surrounding air since it affects the water balance and photosynthesis processes in plants. Humidity levels that are higher support the maintenance of open stomata for photosynthesis and reduce plant evaporation, which helps to promote improved plant growth.

Reduced humidity levels below the ideal threshold will make stomata more resistant, which will slow down the rate of photosynthesis and the uptake of carbon dioxide. On the other hand, a relative humidity that is higher than ideal will negatively impact transpiration rate, which in turn impacts plant growth and leaf development because of a reduced ability to assimilate nutrients.

Table 19.3: Relative Humidity for Some of The Flowering Crops

Flower crop	Relative humidity (%)	Flower crop	Relative humidity (%)
Monopodial Orchid	**80-85**	Carnation	**60-65**
Sympodial Orchid	**45-55**	Bird of paradise	**50**
Chrysanthemum	**60-70**	Heliconia	**40-50**
Gladiolus	**60-70**	Alstromeria	**75-80**
China aster	**50-60**	Gerbera	**50-60**
Anthurium	**80-90**	Michelia champa	**60-80**

19.4.4 Carbon dioxide (CO_2):

The inhibition of oxygen on photosynthesis can be removed by raising CO_2 levels in protected cultivation environments to approximately 900 ppm, which will increase CO_2 fixation rates. Additionally, plants at this elevation experience 20–40% less transpiration, which improves water efficiency. Higher CO_2 levels can also encourage the synthesis of polyamines, which may reverse the senescence-inducing shift brought on by stressors like salinity. Under CO_2 enrichment, stomatal resistance rises more in C4 plants than in C3 plants. Higher CO_2 concentrations can hasten flowering and growth. Because CO_2 accelerates photosynthesis, the process that propels growth, flowers bloom at earlier times. Plants with higher CO_2 levels are able to photosynthesize more effectively, which speeds up growth and promotes earlier flowering. By promoting plant growth, CO_2 enrichment enhances plant productivity and enhances the quantity and quality of flowers produced. However, if light is limiting, adding more CO_2 will not help. Nevertheless, the extra CO_2 allows plants to absorb more of the available light when it is abundant, accelerating the rate of photosynthesis. Blooming - Certain plants that receive short days are unable to bloom at high CO_2 levels. Increased lateral branching results in an increase in the overall number of flowers in carnation. Higher CO_2 concentrations that form basal shoots cause rose bushes to regenerate and weaken their apical dominance.

CO_2 enrichment has several advantages that includes increased photosynthesis and enhanced nitrogen fixation capacity in legumes. Boosted rate of photosynthesis in most plant species, resulting in increased sugar production per unit of absorbed light. Average increases of 13% in vegetative growth (shoot, leaves, stem, and roots), 31% in reproductive output (flowers and seeds), and 34% in seed yield. Enhanced growth in the short term, known as the CO_2 fertilization effect. Increased availability of sugars to nourish root symbionts, promoting faster growth. Reduced water usage per leaf area. Protection against SO_2 damage in CO_2-rich environments. Improved tolerance to salinity in some plants. Inhibition of weed growth

Table 19.4: Impact of CO_2 enrichment on greenhouse ornamental plants' growth and flowering

Crop	CO_2 Concentration (ppm)	Effects
Begonia	700-900	Increased rate of growth, reduced time spent in culture, bigger and more plentiful flowers
Carnation	1000-1500	Superior lateral branching, increased juvenile plant growth rate, increased yield, and improved stem quality
Chrysanthemum	700-900	Better flower quality, shorter culture time, and a higher relative growth rate

Crop	CO_2 Concentration (ppm)	Effects
Gerbera	1600-2200	Overproduction of starch results in a reduction of chlorophyll.
Hibiscus	1000-1500	Early and in greater quantities of flowers
Petunia	1000-1500	Early blooming
Rose	1000-1500	longer and stronger glower stems, reduced number of blind shoots, and increased yield

19.5 Challenges:

19.5.1 Biodiversity and Conservation:

Conservation efforts must prioritize protecting rare and threatened plants, expanding protected areas, acknowledging indigenous knowledge, engaging local communities, and enhancing biodiversity awareness and education, alongside establishing more reserves and germplasm banks.

19.5.2 Genetic improvement:

Cataloging germplasm collections using IPGRI descriptors is crucial for conservation and should be complemented by modern tools like barcoding and the implementation of duplicate sets grown in multiple locations for redundancy. Moreover, developing hybrids and varieties through robust breeding programs tailored to local agroclimates and market demands, as well as evaluating and utilizing genetic resources for pathogen and climate tolerance, is vital for the long-term sustainability of the cut flower trade.

19.5.3 Frontier Science Technologies:

Utilize available facilities for association mapping and marker-assisted selection, integrate GIS and ISSR for effective species-specific surveys, explore rhizosphere microbial community dynamics, and promote flower commercialization via bioreactors for micropropagation technology.

19.5.4 Management of Natural Resources:

Optimize agro-climatic factors for quality flower production, utilizing cost-effective practices like standardized growing media, INM/IPM, quantifying water use efficiency, and exploring carbon sequestration potential in orchid cropping systems.

19.5.5 Bio-Risk Management:

Enhance surveillance, rapid diagnostics, and management strategies for new invasive pests and pathogens.

19.5.6 Policies:

Implement proactive and collaborative adaptation strategies for climate change mitigation, alongside commercializing upgraded technologies and registering genetic fingerprints of rare species and newly released varieties/hybrids, including patenting ornamental-related technologies and documenting indigenous traditional knowledge.

19.5.7 Transfer of Technology:

Conducting constraint analysis, producing high-quality planting material, hosting large-scale technology demonstrations, establishing agro-technology information centers, and promoting participatory approaches can help in reducing the constraints on flower crop production.

The current challenge is the creation of novel, sustainable technologies that can be adjusted to the changing climate while minimising their negative effects on the productive sector. Regarding the floral industry, numerous solutions have been developed in an attempt to find ways to adapt to various problems, such as high temperatures and water constraints.

Identification of potential and productive native ornamental plants, for instance, as well as species tolerant of high temperatures and low soil moisture content, as well as effective and sustainable production systems with low greenhouse gas emissions, such as indoor farms, are a few examples.

Pollutants in water runoff can be removed by developing certain structures, like green roofs. In addition to being aesthetically pleasing, vertical gardens are effective buildings that lower surface temperatures and enhance air quality in built environments.

In conclusion, climate change poses significant challenges to floriculture, impacting various aspects such as growing seasons, plant hardiness zones, water availability, pest and disease pressure, extreme weather events, floral biodiversity, and economic factors.

Temperature, light, relative humidity, and carbon dioxide levels play crucial roles in flower development and production. Effective adaptation strategies, such as adjusting crop selection, implementing water management techniques, and developing resistant plant varieties, are essential for ensuring the resilience and sustainability of the floriculture industry in the face of on-going environmental changes.

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