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Review Article

Climate Change and Its Impact on Floriculture Crops: Adaptation Strategies and Opportunities

Sudhir Kumar Pathak*

Designation of Agriculture, Coordinator (Buxar)

Department of Agriculture Govt. of Bihar

Sam Hingin Bottom Institute of Agriculture Technology & Sciences

*Corresponding Author E-mail: sudhirpathak38@yahoo.com

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ABSTRACT

Climate change has emerged as a significant challenge to the floriculture sector, affecting flower quality, productivity, and market value through rising temperatures, irregular rainfall, drought, floods, and increased pest and disease incidence. These environmental stresses alter flowering time, post-harvest longevity, and ornamental characteristics, threatening sustainable flower production worldwide. Adaptation strategies, including climate-resilient cultivars, protected cultivation, precision irrigation, integrated nutrient management, and digital climate advisory systems, can enhance resilience and productivity. Furthermore, opportunities exist in developing stress-tolerant varieties, adopting smart technologies, and promoting sustainable production practices. Integrating innovative research, policy support, and farmer awareness will ensure climate-resilient floriculture and long-term environmental and economic sustainability.

Keywords: *Climate change; floriculture; phenology; protected cultivation; climate-resilient cultivars.*

INTRODUCTION

Floriculture, the branch of horticulture concerned with the cultivation of flowering and ornamental plants, has evolved into a multi-billion-dollar global enterprise. According to industry estimates compiled by Facts & Factors (2024), the global floriculture market reached approximately USD 59.25 billion in 2023 and continues to grow at a compound annual rate exceeding 6%. The sector encompasses cut flowers, potted plants, bedding species, foliage, and bulbs, with the Netherlands, Colombia, Ecuador, Kenya, Ethiopia, India, and China serving as principal producers (Darras, 2020). Beyond economic value, floriculture supports rural employment, promotes export earnings, and sustains a vibrant horticultural heritage in many developing nations.

Climate change, driven by accelerating greenhouse-gas emissions, has emerged as the single most pervasive threat to agricultural systems worldwide.

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The Intergovernmental Panel on Climate Change (IPCC, 2022) reports that the global mean surface temperature has already risen by approximately 1.1 °C above pre-industrial levels, with continued warming projected throughout the twenty-first century. While much of the climate-impact literature has focused on staple food crops, ornamental and flower crops are equally—if not more—susceptible because they are typically grown for aesthetic quality, where even minor deviations in colour, form, or vase life translate directly into market losses (Kuruppu et al., 2021). Mitchell (2017) further notes that floriculture is uniquely vulnerable because it is concentrated in narrow climatic belts and depends heavily on energy-intensive logistics.

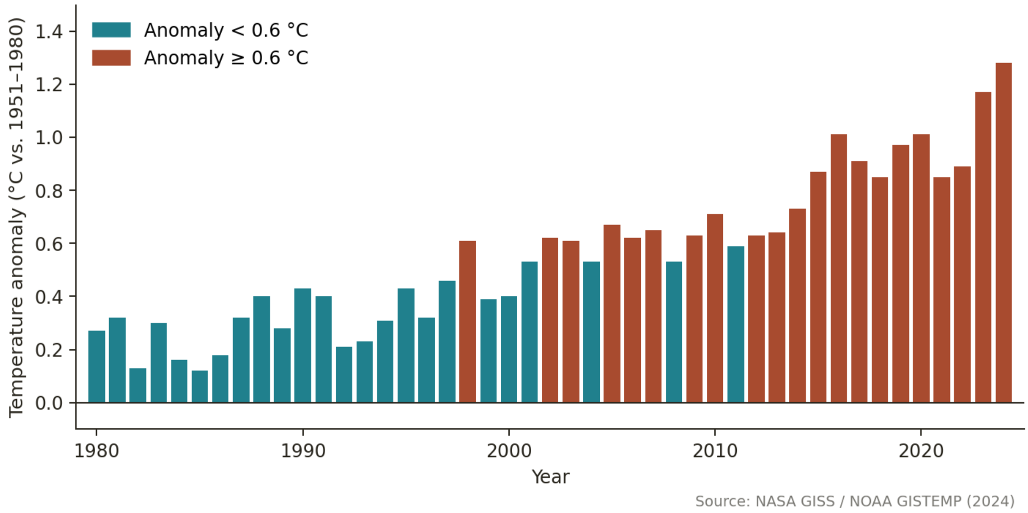

Figure1. Global surface temperature anomaly relative to the 1951–1980 baseline, 1980–2024. Data adapted from NASA GISS and NOAA GISTEMP records

2. Drivers of Climate Change Relevant to Floriculture

Several interrelated climatic drivers act simultaneously on flower crops. Rising mean and night temperatures alter respiration, flowering time, and pigment biosynthesis. Heatwaves of increasing intensity damage delicate floral tissues and disrupt pollination. Variable rainfall and prolonged drought cycles reduce irrigation security in open-field floriculture regions such as East Africa and South Asia (FAO, 2021). Elevated atmospheric carbon dioxide (CO_2) concentrations, although potentially beneficial for photosynthesis, can simultaneously affect biomass partitioning between vegetative and reproductive tissues. Finally, the increased frequency of extreme events—hailstorms, cyclones, and unseasonal frosts—damages greenhouse structures and shortens the productive life of nurseries (IPCC, 2022).

These drivers do not act in isolation. As Hatfield and Prueger (2015) emphasise, the interaction between heat and water stress often produces non-linear yield responses that exceed the sum of single-factor effects. For floriculture, such interactions are especially damaging because ornamental quality is highly sensitive to compounded stresses. A modest temperature increase combined with a short drought episode may collectively cause flower deformities, colour fading, and reduced vase life that no single stressor could produce alone. Furthermore, the indirect socioeconomic drivers — rising energy prices, water-allocation disputes, and tightening environmental regulations — add a second layer of pressure on commercial flower production, particularly in export-oriented regions where margins are already narrow.

3. Physiological and Growth Impacts on Major Floriculture Crops

3.1 Heat stress and photosynthesis

Temperature is the most influential climatic variable for ornamental crops. The optimum growth range for most cut-flower species lies between 18 and 25 °C; deviations beyond this band reduce chlorophyll concentration, accelerate leaf senescence, and impair photosystem II activity (Pearcy & Bjorkman, 1983). In rose (Rosa hybrida), exposure to day temperatures above 32 °C reduces stem length, bud size, and petal number, while raising the proportion of malformed ("bullhead") blooms. Carnation (Dianthus caryophyllus), historically grown in cool subtropical climates, shows reduced petal weight and shortened vase life when night temperatures rise above 18 °C (Sandhu et al., 2020). At the cellular level, sustained heat damages chloroplast thylakoid membranes, disrupts the oxygen-evolving complex, and triggers accumulation of heat-shock proteins that protect but cannot fully restore photosynthetic efficiency, leaving plants visibly less vigorous even after the stress period ends.

3.2 Drought and water stress

Drought reduces cell turgor, restricts nutrient uptake, and triggers oxidative stress through over-accumulation of reactive oxygen species. Gerbera (Gerbera jamesonii) and chrysanthemum (Chrysanthemum morifolium) exhibit pronounced declines in flower diameter and number under sustained water deficit (Kuruppu et al., 2021). Comparative studies indicate that ornamental species differ widely in drought tolerance: marigold (Tagetes spp.) and zinnia show greater resilience, whereas gerbera and lily are highly sensitive (Toscano et al., 2019).

3.3 Elevated CO_2 and pigment chemistry

Elevated CO_2 generally stimulates photosynthesis in C_3 ornamentals, leading to greater biomass and earlier flowering. However, the response is not uniformly positive. Mortensen (2000) showed that long-term exposure to 700 ppm CO_2 in chrysanthemum increased biomass but reduced flower colour intensity due to dilution of anthocyanin pigments. Similar trade-offs have been reported in petunia and snapdragon, suggesting that CO_2 fertilisation may improve quantitative yield while diminishing qualitative market value.

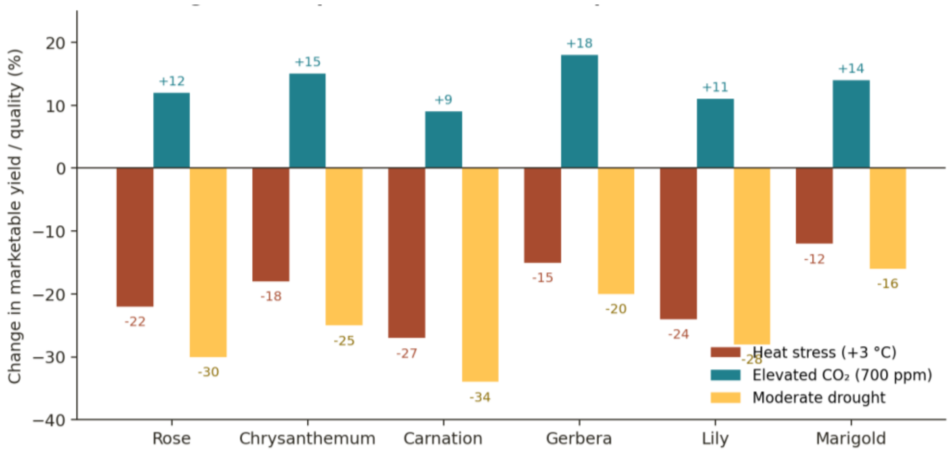

Figure2. Comparative response of six major floriculture crops to heat stress, elevated CO_2, and moderate drought, expressed as percentage change in marketable yield relative to control conditions

4. Phenological Shifts and Flowering Time

Phenology—the timing of biological events—is a sensitive indicator of climate change. Fitter and Fitter (2002) documented earlier flowering across hundreds of UK plant species, attributing a mean advancement of 4.5 days per decade to rising temperatures. More recent meta-analyses confirm that ornamentals such as tulip, narcissus, and rose now flower two to four days earlier per °C of warming (Menzel et al., 2020). Such shifts disrupt the synchrony between cultivation cycles and market demand peaks. For example, premature blooming of tulips in the Netherlands or chrysanthemums in India can produce surplus supply before peak festival demand, depressing farm-gate prices.

Phenological mismatch also affects pollinator-dependent ornamental species. As Hegland et al. (2009) describe, asynchronies between flowering and pollinator activity reduce seed set in open-pollinated ornamentals such as sunflower hybrids and cosmos, with downstream effects on hybrid seed production. In photoperiod-sensitive species such as chrysanthemum and poinsettia, the combined effect of warmer nights and shifting day-length perception can disturb the precisely timed production schedules used by commercial growers to supply festive markets. Without recalibration of cultivar selection and lighting protocols, growers risk persistent off-season blooming that depresses prices and erodes brand reputation in premium export channels.

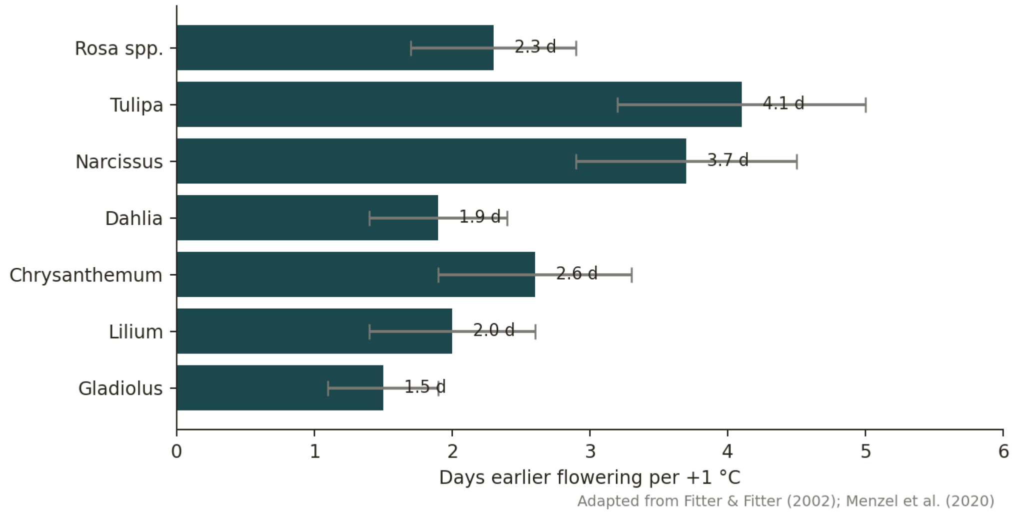

Figure3. Phenological advancement (days earlier flowering per +1 °C) in selected ornamental species. Bars represent mean shifts; error bars show standard error compiled from multi-year datasets

5. Pests, Diseases, and Post-harvest Quality

Warmer winters and humid conditions expand the geographic range of important floriculture pests, including the western flower thrips (Frankliniella occidentalis), two-spotted spider mite (Tetranychus urticae), and several aphid species. Fungal pathogens such as Botrytis cinerea—the cause of grey mould in rose, gerbera, and lily—proliferate under elevated humidity and condensation typical of poorly ventilated greenhouses (Williamson et al., 2007). Mitchell (2017) further reports that vector-transmitted viral diseases of ornamentals are likely to expand into temperate production zones.

Post-harvest quality also declines under climate stress. Higher pre-harvest temperatures shorten vase life, while heat events disrupt the cold chain between growers and consumers. Cevallos and Reid (2001) demonstrated that even brief exposures to 30 °C during transit can halve the vase life of premium roses. Maintaining post-harvest cold chains in tropical exporting nations therefore represents a critical—yet often overlooked—climate-adaptation priority.

6. Adaptation Strategies

6.1 Genetic improvement and biotechnology

Conventional breeding for heat- and drought-tolerant cultivars remains foundational. Modern marker-assisted selection and genome editing (CRISPR/Cas9) accelerate this process by enabling targeted introgression of stress-tolerance genes. Recent advances in chrysanthemum have identified DREB and HSP70 family genes that confer enhanced thermo-tolerance (Su et al., 2019). Polyploid breeding and interspecific hybridisation in lily, rose, and gladiolus have also produced cultivars better suited to warmer climates (Van Tuyl & Arens, 2011).

6.2 Protected cultivation and microclimate management

Greenhouses, polyhouses, shade nets, and naturally ventilated structures buffer crops from external climate extremes. Evaporative cooling, fogging, and high-pressure misting can reduce greenhouse temperatures by 5–8 °C in arid environments. Hydroponic and aeroponic systems decouple production from soil quality and reduce water consumption by 60–80% compared with open-field cultivation (Sambo et al., 2019). For smallholders, low-cost insect-proof net houses and shade structures represent affordable entry points into climate-smart floriculture.

6.3 Precision irrigation, mulching, and biostimulants

Drip irrigation coupled with soil moisture sensors enables deficit irrigation strategies that maintain quality while saving water. Mulching with organic residues or biodegradable films reduces evaporative losses, stabilises root-zone temperature, and suppresses weed competition. Foliar application of biostimulants such as seaweed extracts, humic acids, and microbial inoculants has been shown to enhance heat and drought tolerance in carnation, gerbera, and marigold (Rouphael & Colla, 2020). Plant growth-promoting rhizobacteria and arbuscular mycorrhizal fungi further improve nutrient uptake, root architecture, and antioxidant capacity, allowing plants to maintain quality under suboptimal water and temperature conditions. These low-cost interventions are particularly relevant for resource-constrained growers in developing economies, where capital-intensive cooling infrastructure is often unaffordable.

6.4 Digital agriculture and decision-support tools

Sensor networks, Internet-of-Things (IoT) climate controllers, and artificial-intelligence models now provide real-time microclimate management and disease forecasting. Mobile-based advisory platforms deliver location-specific climate forecasts to flower growers in Kenya, Ethiopia, and India, enabling proactive irrigation and pest management. Coupled with crop insurance and carbon-credit markets, such digital tools strengthen the economic resilience of floriculture enterprises (FAO, 2021).

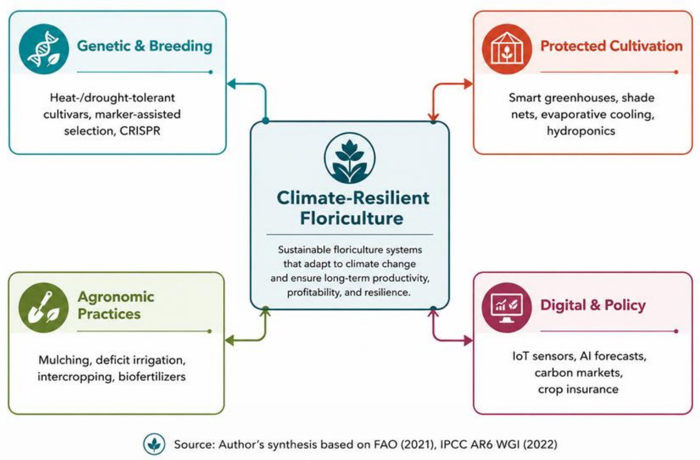

Figure4. Integrated adaptation framework for climate-resilient floriculture, illustrating four complementary pillars: genetic improvement, protected cultivation, agronomic practices, and digital/policy interventions

7. Opportunities and Emerging Directions

Despite its vulnerabilities, climate change creates several opportunities for the floriculture sector. First, the growing global consumer demand for sustainably produced flowers opens premium markets for low-carbon, water-efficient, and fair-trade certified blooms (Darras, 2020). Second, climate-resilient cultivars and water-saving production systems represent a significant innovation frontier with strong commercial potential. Third, geographic redistribution may benefit temperate-zone producers as historically dominant tropical regions face escalating climatic risks. Fourth, integrating floriculture with carbon farming, pollinator conservation, and urban green infrastructure can position the sector as part of broader climate-mitigation solutions.

Public–private partnerships, regional research consortia, and farmer training programmes will be essential to translate these opportunities into practice. Investment in genetic resources, gene-bank conservation of wild ornamental relatives, and capacity-building in protected-cultivation technologies should be prioritised in national agricultural research agendas. Equally important is the inclusion of women growers and small landholders, who form the backbone of floriculture in many South Asian and East African economies, in adaptation planning and benefit-sharing mechanisms.

Emerging interdisciplinary fields such as bioeconomy modelling, life-cycle assessment of flower supply chains, and ecosystem-services valuation provide new tools to quantify the trade-offs between productivity, sustainability, and resilience. Coupled with climate-risk insurance products and traceable, low-carbon export labels, these tools can transform the floriculture sector from a passive recipient of climate impacts into an active contributor to climate action.

CONCLUSION

Climate change presents a complex and multifaceted challenge for global floriculture, with documented impacts spanning physiology, phenology, pest dynamics, post-harvest quality, and market performance. Major crops such as rose, chrysanthemum, carnation, gerbera, lily, and marigold show distinct but overlapping vulnerabilities to heat, drought, and humidity extremes. Nevertheless, the same set of stressors also drives innovation: heat-tolerant cultivars, smart greenhouses, precision irrigation, biostimulants, and digital decision-support systems together offer a robust adaptation portfolio. An integrated approach that combines genetic improvement, protected cultivation, sound agronomy, and supportive policy frameworks is essential to safeguard the economic and ecological contributions of floriculture. With timely investment in research, infrastructure, and farmer capacity, the floriculture industry can not only adapt to climate change but also emerge as a leading example of climate-smart, sustainable horticulture for the decades ahead.

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