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# Impact of Climate Change on Floriculture Industry of India

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## Introduction

Basically, climate change is the increase in the atmospheric temperature due to enhanced levels of greenhouse gases (GHGs) i.e. $CO_2$, Methane ($CH_4$) and nitrous oxide ($N_2O$) in the atmosphere. It is manifested in terms of occurrence and repetition of events like droughts, melting of glaciers and rising sea levels. Climate change affects directly or indirectly the agricultural activity including crops, soils, livestock and pests. Directly, increase in temperature reduces crop duration, increase crop respiration rate, alteration in photosynthesis process, survival and distribution of pest population, hasten nutrient mineralization in soils, decrease fertilizer use efficiency and increase evapo-transpiration. Indirectly, it influences agricultural land use pattern, intensity of droughts and floods, soil organic matter transformation, soil erosion, changes in pest complex and decline in arable areas. In India, where half of the agricultural land is rainfed, climate change directly affects crop yields, soil processes, water availability, and pest dynamics (Pathak, 2023).

At present, $CO_2$ concentration is 350 ppm. It would be 550 ppm in 2040 AD, 600 ppm in 2060AD and 650-750 ppm in 2075 AD. Doubling of $CO_2$ concentration generally increases temperature about 2.3± 1.6°C. Assuming a global temperature increase of about 4°C by 2080 AD the output of Indian Agriculture is projected to down by 30-40%.

According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures are projected to rise by 1.0 to 3.5°C by 2100, with a doubling of $CO_2$ levels potentially increasing temperatures by 1.5 to 4.5°C (Yadav et al., 2021). These changes present serious challenges to farmers and pose a significant threat to agriculture and global food security. In the floriculture industry, the differences in $CO_2$ footprints and overall environmental impact are substantial. The industry must seek dynamic modifications for future production and sale. Life cycle assessment (LCA) has become an essential tool for evaluating the environmental impact of horticultural products, from production to handling and transportation. It involves calculating inputs (energy and materials) and outputs (releases to air, water, soil, etc.) at every step of the production chain.

***General impact of climate change*** (Mitchell and Tanner, 2006)

***Agriculture***: Shifts in food growing areas, changes in crop yields, increased irrigation demands and increased crop pests and diseases in warmer areas.

***Water resources***: Changes in water supply, decrease in water quality, increased drought and increased flooding.

***Forests***: Changes in forest compositions and locations, disappearance of some forests, increased fires from drying of forest trees and grasses and loss of wild habitat and species.

***Biodiversity***: Extinction of some animal and plant species, loss of habitats and disruption of aquatic life

***Weather Extremes***: Prolonged heat waves and droughts, increased flooding and more intense hurricanes, typhoons, tornadoes and violent storms.

***Sea Levels and Coastal Areas***: Rising sea levels, flooding of low-lying islands and coastal cities, flooding of coastal estuaries, wetlands and coral reefs, beach erosion, disruption of coastal fisheries and contamination of coastal aquifers with salt water.

***Human Population***: Increased deaths, more environmental refugees and increased migration.

***Human Health***: Increased deaths from heat and epidemic diseases, disruption of food and water supplies, spread of tropical diseases to temperate areas and increased water pollution from coastal flooding.

### *Climate change and Ornamental plants*

Rising winter temperatures due to climate change leading to the less precipitation in the form of snow and changing precipitation pattern with the enhanced number of dry days and increased concentration of rainy days influencing the temperate horticulture. In fact, the climate change is expected to bring both opportunities such as expansion of areas, addition of new crop genotypes and threats like shrinking of area, extinction or shifting of crop species including cropping pattern. Upward shift has already been noticed in some species for example *Aconitum heterophyllum*, *Lilium polyphyllum*, *Sorbus lanata* etc. Diversity of some alpine species such as *Hippophae* spp, *Betula utilis*, *Cotoneaster* spp., *Nordostychus grandiflora* become vulnerable, and their distribution is gradually narrowed. The rhododendrons and other woody ornamentals of lower hills have begun to invade the alpine areas thus changing the composition of plants. Socioeconomic survey has already identified change in precipitation rate, snowball, land degradation, drying up of water resources, outbreak of insect pests and diseases, phenological changes, change in cropping pattern and food shortages are good indicators of climate change.

In ornamental plants, increased temperatures can drastically affect photosynthesis and flowering, two key factors that influence overall plant performance. For example, rising temperatures from 20°C to 40°C have been shown to significantly reduce the photosynthetic activity of species such as *Agastache urticifolia*, *Petunia x hybrida*, *Capsicum annuum*, *Plumbago auriculata*, and *Catharanthus roseus*. Similarly, temperature increases from 14°C to 26°C may shorten the time to anthesis in annuals like *Tagetes erecta* and *Antirrhinum majus*.

Climate change affect some flowers fail to bloom, others will produce flowers of smaller size, improper colour development and shorter blooming period. The production of flower crops grown on open field conditions like marigold, gladiolus, tuberose, rose, annuals will be affected by climate change. Other ornamentals such as orchids, rhododendrons, balsam which needs frost and low temperature for flowering are adversely influenced.

Temperature extremes not only influence the timing and quantity of flowering but also affect flower quality. Higher temperatures, such as 32°C, have been linked to a reduction in the number of flowering buds and smaller flower diameters in species like *Antirrhinum majus* and *Impatiens walleriana*. Moreover, temperature during plant growth plays a critical role in pigment production, directly influencing flower colour. For example, anthocyanin production, which contributes to the vibrant colours in flowers, is most effective at low to medium temperatures. However, when temperatures exceed 40°C, anthocyanin production declines, resulting in reduced colour intensity.

### *Climate change and orchid biodiversity*

Climate change due to global warming interacts with habitat loss and fragmentation, introduced and invasive species and population growths and many ecosystems are likely to undergo severe modification. In Asia, climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development. Semi-arid vegetation will tend to be replaced by arid vegetation. Levels of precipitation are likely to change radically in many areas of the world. Increasing temperature may result in vegetational zones gradually moving vertically up mountain sides, both permitting tropical species to subtropical areas, subtropical species to temperate areas and eliminating the species in the highest zones (Liu et al, 2010).

Epiphytic orchids may be affected in various ways by changes in the availability of light, nutrients and moisture. Climate change is major threat to pollination services and there is a need to conserve plant communities in which orchids live. The combination of higher temperatures and lower rainfall may make forests more susceptible to fire and it may lead to extinction of local species. During 1984, World Orchid Conference held in Miami, it was proposed that the orchid community should start banking orchid seed as an insurance against possible losses of species from their habitats in the wild. Majority of orchid species can tolerate dry storage for many decades when stored at -20°C. Liquid nitrogen storage may produce further extensions of life spans of orchid seeds. Living collections are recently underutilized as a conservation tool and there is a need to do more to induce members of the wider orchid community (De et al, 2012).

***$CO_2$ enrichment and greenhouse ornamentals*** (De et al, 1998)

The carbon dioxide is a basic need of all green plants and fixes through Calvin-Benson Cycle. The rate of photosynthesis increases with increase in $CO_2$ concentration. Calvin-Benson Cycle begins with the carboxylation of a purpose sugar (RUBP) which is catalysed by the enzyme RUBPclase. Unfortunately, under normal atmospheric conditions by vol $O_2$ competes with $CO_2$ on the active site of enzyme and directly lessen the rate of $CO_2$ fixation. Further, the enzyme is capable of functioning as an oxygenase, this activity results in the formation of a glycollate compound which is further metabolized in a light dependent reaction to release $CO_2$. This loss of $CO_2$ in the light is formed as photorespiration. Therefore, under protected cultivation, by increasing the $CO_2$ level to 900 ppm, this $O_2$ inhibition of photosynthesis is eliminated due to the increased $CO_2/O_2$ ratio. Rising the $CO_2$ concentration reduces the transpiration of plants by 20-40%. In general, polyamines/ethylene ratio is high in young stage while changes of low in old ones and stress condition like salinity may cause a faster shift of the balance from its juvenility causing to its senescence causing ratio. The $CO_2$ elevation may cause the reverse shift by enhancing polyamine synthesis. The $CO_2$ enrichment increases stomatal resistance in $C_4$ plants than in $C_3$ plants.

***Advantages of $CO_2$ enrichment***

- Increases in photosynthesis and brings a dramatic increase in nitrogen fixing ability in legumes.
- Increases rate of photosynthesis in most of the plant species by producing more sugars per unit of light absorbed.
- Increases in vegetative growth (shoot, leaves, stem, roots) on an average 13% and their reproductive output (flower and seeds) by an average of 31% and grain yield by 34%.
- Short-term growth enhancement is called $CO_2$ fertilization effect.
- Plants associated with root symbionts have more sugars to feed them and in exchange should receive additional nutrients thereby improving growth.
- Reduces water consumption/unit area of leaf.
- $CO_2$ rich conditions also protect from $SO_2$ damages.
- $CO_2$ atmosphere enables some plants to overcome salinity stress.
- It suppresses weed growth.

***Morphological changes at elevated $CO_2$***

***Leaf growth***: The $CO_2$ enrichment increases the number of leaves /plant in Saintpaulea, Nephrolepis and gerbera. Total leaf weight increases due to one or two extra palisade cell layers and more densely packed palisade mesophyll cells.

***Stem growth***: Plants subjected to elevated $CO_2$ are in general heavier because dry weight /unit stem length in greater.

***Root formation***: Elevated levels of $CO_2$ applied in the form of carbonated mist increases the per cent of rooting and number of roots/cuttings in Chrysanthemum, Juniperus and Rhododendron due to increased effects of Carbohydrates.

***Branching and tillering***: An increased number of lateral shoots caused by $CO_2$ enrichment has been observed in roses, carnation and gypsophila due to lowering of apical dominance at elevated $CO_2$.

***Flowering***: At an elevated $CO_2$, flowering of short-day plants is prevented for some plants. Total number of flowers in carnation is increased due to increased lateral branching. Formation of basal shoots by higher $CO_2$ concentration led to renewal of rose bushes and due to weakening of apical dominance.

| ***Crop*** | ***$CO_2$ concentration*** | ***Effects*** |
|---|---|---|
| Begonia | 700-900 ppm | Enhanced growth rate, shorter culture time, larger flowers and abundant flowers |
| Hibiscus | 1000-1500 ppm | Earlier and more number of flowers |
| Chrysanthemum | 700-900 ppm | Higher relative growth rate, shorter culture time, better flower quality |
| Rose | 1000-1500ppm | Reduced number of blind shoots, higher yield, longer and stronger glower stems |
| Tulip | 1000-1500ppm | No beneficial effect |
| Carnation | 1000-1500ppm | Better lateral branching, higher growth rate of young plants, higher yield and better stem quality |
| Petunia | 1000-1500ppm | Earlier flowering |
| Dieffenbachia | 700-900 ppm | Faster growth |
| *Ficus elastica* | 1000-1500ppm | Larger leaves |

***Table 1:*** Effect of $CO_2$ enrichment on growth and flowering of greenhouse ornamentals.

| ***Crop*** | ***Injury level*** | ***Description*** | ***Reasons*** |
|---|---|---|---|
| Chrysanthemum | 1500-3000 ppm | Chlorosis | Excessive starch causes deformation of chloroplast with compression of grana |
| Gerbera | 1600-2200 ppm | Chlorosis | Excessive starch formation causes chlorophyll breakdown |

***Table 2:*** Visible injuries at elevated $CO_2$.

## *Impact of Climate Change on Flower Crops and their Health*

***Altered Blooming Cycles & Flower Quality***: Temperature changes may lead to early or delayed blooming, disrupting market availability and the timing of flowering events crucial for festivals and weddings in India. Higher temperatures and altered precipitation patterns can lead to reduced flower size, poor colour development, and diminished fragrance (Paiva, 2023).

***Pest and Disease Pressure***: Climate change has led to the emergence of new pests and diseases and has increased the intensity of existing ones. Warmer temperatures and higher humidity provide favourable conditions for pathogens, thereby increasing the vulnerability of flowers to infestations. In warmer climates, the prevalence of pests and diseases tends to rise, leading to crop damage and reduced yields (Singh & Sisodia, 2015). Climate change can directly affect the development and survival of pathogens and herbivorous insects, as well as their natural enemies and competitors. Additionally, it can indirectly alter the physiological responses of host plants, particularly their defence mechanisms. Variations in temperature and humidity may influence the reproductive potential of pathogens and pests, their dispersal abilities, and their interactions with competitors (Darras, 2020).

***Impact on Indigenous Flower Species***: Native flower species, adapted to specific climatic conditions, may struggle to survive in changing climates, leading to a loss of biodiversity in India.

***Impact on Greenhouse Production***: Climate change affects greenhouse production, where controlled environments are key. Higher energy costs for cooling and heating, and the need for advanced climate control technologies, increase production costs.

***Market and Economic Impact***: Disruptions in production due to climate change can lead to supply shortages, price fluctuations, and reduced export competitiveness. As a major exporter of cut flowers, India could face challenges in maintaining its market share globally.

***Shift to Artificial Flowers***: In addition to climate-related challenges, the floriculture industry is also impacted by changing consumer preferences. There is a growing trend towards the use of artificial flowers, particularly during festivals, due to their durability and lower cost compared to natural flowers. This shift is not only affecting the livelihoods of flower vendors but also raises environmental concerns, as artificial flowers are typically made from non-biodegradable materials that pose significant waste management challenges.

### *Climate change and Landscape gardening*

Interior landscape plants such as *Hedera helix*, *Chlorophytum comosum*, *Epipremnum aureum*, *Spathiphyllum* "Mauna Loa', *Aglaonema modestum*, *Chamaedorea* spp., *Sansevieria trifasciata*, *Philodendron domesticum*, *Dracena mariginata*, *Dracena fragrans* are useful to enhance indoor environmental quality, to improve workplace efficiency, to improve visitor's perceptions, to reduce dust levels, to reduce noise, to filter the air in indoor environment and to increase humidity in the workplace. Practice of roof gardening can clean water runoff of pollutants, filter the air that circulates near the roof and cool the air. Vertical gardening improves air quality and reduce surface temperature in the built environment. Lawn development improves air quality by filtering air pollutants.

Landscaping reduces air and water pollution, mitigate health risk for wildlife and people, maintain species diversity, reduce costs for heating and cooling of building and reduces noise pollution. Informal gardening imitates the nature and strives to produce a natural effect in a closed area. Wild gardening style can create a pleasing blend of beauty and utility with ecological and environmental needs. Public Park creates an environment of growing things, rest, relaxation and breathing space for people of the area of location. Development of an industrial garden checks the pollution, beautify the area, arrests the drifting dusts and cut down the noises.

### *Adaptation & Mitigation Strategies*

***Enhancing Crop Resilience***: Breeding Strategies for Climate Change Adaptation: Abiotic stresses, including temperature extremes, drought, and salinity, severely impact crop yields and pose significant threats to global food security. In response, breeding strategies aimed at enhancing crop resilience to these environmental stresses are critical to maintaining agricultural productivity in the face of climate change. Breeding for drought resistance, for example, focuses on developing varieties that can withstand limited water availability, a growing concern due to the increasing frequency and severity of droughts worldwide. Research efforts are directed at identifying and selecting genotypes with traits such as deeper root systems, efficient water use, and enhanced tolerance to osmotic stress. Similarly, breeding programs for heat tolerance aim to develop crops capable of maintaining yield and quality under elevated temperatures by selecting for traits such as heat-shock protein production, membrane stability, and photosynthetic efficiency. In floriculture, these strategies are crucial for developing flower varieties that can thrive in the changing climate.

***Precision Agriculture***: Implementing precision agriculture techniques, such as soil moisture sensors and climate monitoring systems, can optimize resource use and mitigate the effects of climate variability on floriculture. Precision farming offers a way to reduce costs, lower inputs, and improve product quality while minimizing environmental impact.

***Policy Measures & Government Initiatives***: The Indian government has initiated several programs to support farmers in adapting to climate change, including the Pradhan Mantri Fasal Bima Yojana (PMFBY) and the National Mission for Sustainable Agriculture (NMSA). These initiatives focus on improving resilience through crop insurance, drought management, and promoting climate-resilient agricultural practices.

### *Challenges*

### *Biodiversity and Conservation*

Nearly 12.5 % of the global vascular flora facing extinction and therefore, conservation of rare and threatened plants are of international importance.

- Conservation of biota in fragmented landscapes, protecting and increasing the habitat, improving habitat quality, increasing connectivity, managing disturbance processes in the wider landscape, planning for the long term, and learning from conservation actions undertaken.
- To maintain the tropical biodiversity, there is no substitute for primary forests, there is a need to increase the forest area under protected area network.
- The value and importance of indigenous peoples' and local communities' customary sustainable use and traditional knowledge in conserving and upholding biodiversity, land- and seascapes, and protected areas should be acknowledged. Incentives may be needed to entice people to participate in conservation and recovery programs.
- Implementation of community-based projects on biodiversity conservation provides opportunities to actively engage and involve local and indigenous people.
- There is an urgent need to develop Biodiversity Profile of India so that we have adequate knowledge on existing species, ecosystem and genetic resources and threats to them to monitor and report on biodiversity (e.g., extinction rates, biodiversity loss). The main causes for a lack of knowledge on biodiversity loss include limited number of scientific experts, national indicators, research, finance and available technology and lack of biodiversity specific educational program.
- More biosphere reserves, sanctuaries and germplasm banks need to be established.
- Promoting education and awareness about plant diversity conservation and sustainable utilization and biodiversity conservation at the local level to be encouraged.
- An integrated orchid conservation approach including conservation genetics, mycorrhizal associations, pollinators interactions, in- situ conservations (Biosphere Reserves, National Parks, Sacred Grooves, Gene Sanctuary and Individual Trees) and ex situ conservations (Field Gene Banks, Botanical Garden, Herbal Garden, In- vitro-conservation, Cryo-preservation and DNA Bank) will be taken up.

### *Genetic Improvement*

- Genera and species wise cataloguing of all germplasm collection using IPGRI descriptors.
- The rich diversity of ornamental plants in the country requires a strong concepted Network Approach mode. In view of the IPR regulations, it is the paramount importance to protect our germplasm using modern tools of bar coding. A network project involving groups with identical interest between universities and ICAR. This germplasm should be conserved with the duplicate sets grown in at least two locations, properly catalogued and characterized with national number obtained from NBPGR avoiding duplication. Cryopreservation to conserve germplasm can be taken up in collaboration with NBPGR.
- At present, cut flower trade is solely based on the hybrids derived from varietals, interspecies and inter-generic crosses. Building up a strong crop improvement programme based on sound breeding methodologies that will yield into development of hybrids/varieties of internationally acceptable quality traits. It is essential to develop own hybrids suitable for varied agroclimatic conditions for our country fulfilling the basic requirements of market demands.
- Evaluation of newly evolved genotypes to suit specific agro-ecological conditions.
- Locating sources of resistance for biotic an abiotic stress using conventional and biotechnological tools and developing varieties with high yield, quality and specific traits.

### *Frontier Science Technologies*

- It is essential to use the available hybrids and segregating populations to develop Association mapping. Hence the facilities available at IIHR, DFR, IIAB and NRCO may be used to develop genome assistant or marker assistant selections.
- The lead obtained in GIS with the help of facilities of ISSR to cover various ornamental species which aid in location specific as well as species specific survey effective.
- Characterization of rhizosphere microbial community structure and effect of engineered nanoparticles on microorganisms in the rhizosphere and phyllosphere.
- Commercialization of flowers through bioreactors covering micropropagation technology to industry in network mode.

### *Management of Natural Resources*

- Cost effective agro-climatic management through optimization of a number of factors like light, temperature, humidity, water, air, growing media and nutrition for quality flower production. The standardization of growing media using cheap and indigenous materials such as leaf ferns, leaf moulds, green moss etc. may be explored.
- Development and popularization of cost-effective agricultural practices (INM/IPM) for increasing productivity.
- Quantification of water use efficiency and water requirements in various commercial flowers based on growth habit.
- Carbon sequestration potential in orchid based cropping systems.
- Post harvest and Value Addition.
- Development of location specific complete protocols starting from pre-harvest, harvesting, post-harvest techniques upto domestic and international markets for major commercial flowers.
- Developing a comprehensive approach on value added products from wild ornamentals including species trade, drying, flower arrangements, herbal medicines, edible products and other aesthetic and aromatic products.
- Bio-prospecting using bioinformatics tools.

### *Bio-risk Management*

- Surveillance, identification and characterization of new invasive insect pests and pathogens.
- Pest-risk analysis.
- Development of rapid and reliable diagnostics kits against pests and pathogens including invasive species.
- Management alert and control of new invasive insect pests and pathogens.

### *Policies*

- Commercialization of the new upgraded technologies.
- Genetic finger printing of rare, endangered and threatened species and their registration.
- Finger printing and registration of newly released varieties or hybrids.
- Patenting technologies related to ornamentals.
- Confirmation and Documentation of ITK's.

### *Transfer of Technology*

- Constraint analysis and impact assessment of new technologies.
- Production of quality planting materials , distribution and commercialization.
- Large scale demonstration of proven technologies through training and FLD's.
- Establishing agro-technology information centre like ITMU, AKMU, FPO's.
- Participatory planting material production of commercial flowers and other valuable ornamental species.

## Conclusion

Climate change poses a significant threat to India's floriculture industry, impacting production, quality, and market dynamics. Addressing these challenges requires a combination of adaptive strategies, including breeding for climate resilience, precision agriculture, and supportive government policies. In parallel, the industry must also respond to shifting consumer preferences and the environmental implications of artificial flowers. By taking proactive steps to adapt to and mitigate the impacts of climate change, India's floriculture industry can continue to thrive in the face of growing environmental challenges.

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