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Review Article

IMPACT OF CLIMATE CHANGE ON FLORICULTURE AND LANDSCAPE GARDENING

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Abstract: The Climate change affects directly or indirectly the agricultural activity including crops, soils, livestock and pests. Due to global warming it interacts with habitat loss and fragmentation, introduced and invasive species and population growths and many ecosystems are likely to undergo severe modification. CO_2 enrichment increases rate of photosynthesis in most of the plant species by producing more sugars per unit of light absorbed. A number of strategies are followed up for conservation, multiplication, production, improvement and protection of valuable ornamental species and varieties

Keywords: Climate change, ornamental plants, landscape gardening, floriculture

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Introduction

The 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. 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%.

General impact of climate change [1]

Agriculture

- Shifts in food growing areas
- Changes in crop yields
- Increased irrigation demands
- Increased crop pests and diseases in warmer areas

Water resources

- Changes in water supply
- Decrease in water quality
- Increased drought
- Increased flooding

Forests

- Changes in forest compositions and locations
- Disappearance of some forests
- Increased fires from drying of forest trees and grasses
- Loss of wild habitat and species

Biodiversity

- Extinction of some animal and plant species
- Loss of habitats
- Disruption of aquatic life

Weather Extremes

- Prolonged heat waves and droughts
- Increased flooding
- 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
- Contamination of coastal aquifers with salt water

Human Population

- Increased deaths
- More environmental refugees
- Increased migration

Human Health

- Increased deaths from heat and epidemic diseases
- Disruption of food and water supplies
- Spread of tropical diseases to temperate areas
- Increased water pollution from coastal flooding

Climate change and Hill Horticulture

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.

Trend analysis of last decades have already indicated that in mid hills farmers have shifted from apple to vegetables like cole crops and other fruits like pome granate, kiwi *etc*. While at higher altitudes, farmers are being benefitted due to increased temperature and longer growing period with cultivation of apple, potato, pea, cole crops, beans, capsicum and medicinal plants. 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.

Climate change and flower production

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. The higher ambient temperature can have direct impact on volatile fragrances that the flowers emit, deterioration of pigments leading to dull shades, shift in insect pest and disease outbreaks, absence of winter chilling will reduce flowering, reduced post-harvest life, poor pollination and seed set [2]. Changing pattern in photoperiodiism and thermo-periodiism would greatly alter the flowering pattern in flowers such as chrysanthemum, poinsettia and carnation. Due to direct impact small scale players who depend on rain-fed floriculture will be extremely vulnerable to climate change.

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 tropical countries, environmental changes are reported to affect biodiversity in association with enhanced industrial development and as a result arid plants will replace the semi-arid plants. Enhanced temperature can cause shifting of tropical species to subtropical zones, subtropical species to temperate belts and extinct of the species in the highest elevations [3]. 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. In World Orchid Conference held in Miami during 1984, the proposal on storing orchid seed was taken as an insurance against genetic erosion of species from their natural habitats. Most of orchid species can be stored dry at -20°C. Liquid nitrogen may be used for enhancing of life spans of orchid seeds further. Emphasis should be given on living collections for conservation management and more number of members of orchid community must be involved for the purpose [4].

CO_2 enrichment and greenhouse ornamentals [5]

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 RUBP clase. 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 CO2 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 protects 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 lead to renewal of rose bushes and due to weakening of apical dominance.

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 work place [6]. 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 wild life and people, maintain species diversity, reduce costs for heating and cooling of building and reduces noise pollution [7]. 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.

Table-1 Effect of CO_2 enrichment on growth and flowering of greenhouse ornamentals

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 2. Visible injuries at elevated

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

Challenges [8]

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 in order 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. These germplasms 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 agroclimate for our country fulfilling the basic requirements of market demands.
- Evaluation of newly evolved genotypes to suit specific agro-ecological conditions
- Identification and utilization of genetic resources tolerance to pathogens and climate change through traditional and improved breeding techniques and evolving lines having quality 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 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 insects 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

- Anticipatory or reactive, private or public or autonomous planned adaptation to mitigate the adverse effects of climate change [9].
- 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
- Participatory planting material production of commercial flowers and other valuable ornamental species

Application of review: The review article will be useful for plant breeders to develop varieties tolerant to abiotic stresses and to prepare high-resolution models.

Review Category: Climate change

Abbreviations:
RUBP: Ribulose-1,5-bisphosphate
NBPGR: National Bureau of Plant Genetic Resources
IIHR: Indian Institute of Horticultural Research
DFR: Directorate of Floriculture Research
NRCO: National Research Centre for Orchids
ISSR: Inter Simple Sequence Repeats
GIS: Geographic Information System
INM: Integrated Nutrient Management
IPM: Integrated Pest Management
ITK: Indigenous Technical Knowledge
FLD: Front Line Demonstration
ITMU: Institute Technology Management Unit
AKMU: Agriculture Knowledge Management Unit

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