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Climate Resilient Horticulture Practice: An Effective Approach Toward Climate Change

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ABSTRACT

Horticulture is the rapidly growing sector in India and has about 320.48 million tons of production. Horticulture crops are temperature sensitive and require proper flowering and fruit set temperature. Climate change is a severe hazard to horticultural crops as it causes an increase in temperature, unpredictable rainfall, drought, and extreme weather conditions, which cause low yield and affect the overall production, sustainability and income. Climate resilient horticulture technique uses different types of tools and practices to mitigate the effect of climate on the crop, which include the development of heat tolerant, draught tolerant and salt tolerant varieties, micro irrigation techniques, crop management practices and soil management techniques to make plants more resilient toward the climate. In this article, we will discuss climate change and strategies to tackle the change using soil management practices, genetic improvement, irrigation practices, controlled cultivation practices and government policies to boost climate resilience farming.

Keywords: *Climate Resilience, Mitigation, Adaptation, Heat Tolerance, Controlled Cultivation Practices*

Introduction

Horticulture crop production in India contributes about 30% of GDP by using only 13.1% of the total cropped area. India ranked 14th in total vegetable exports and 23rd in total fruit exports. It includes cultivating fruits, vegetables, flowers and medicinal and aromatic crops and is grown in diverse climatic ranges from tropical, sub-tropical and temperate. Horticulture crops are a rich source of vitamins, minerals, macro and micro nutrients. Horticulture has emerged as the best option for expanding food requirements and food safety. It plays a vital role in India's economy by providing income to rural areas. Climate is one of the most critical factors governing plants' growth, development, yield and quality in various ways. India has the best climate for the growth of different horticulture crops as it has diverse soil with different agro-

climatic zones. This provides a good opportunity for a variety of horticultural crops to grow to their full potential and meet their requirements. Climate change is one of the most concerning factors affecting the horticulture sector's overall growth. It includes changes such as increasing temperature, altered rainfall, soil erosion, drought and floods, *etc*., which are also causing fatal effects on the plants and environment. This serious threat requires control measures to reduce its hazardous effect by adapting various strategies and techniques to battle climate change.

What Is Climate Change?

Climate change is defined as the alteration of climatic conditions that contribute directly or indirectly to human activities. These activities lead to changes in the alignment of the global atmosphere and are in addition to the natural variability of climate observed over a comparable time period.

According to the United Nations Organization on Climate Change, Climate change is the change in long-term temperature and weather patterns. This shift can be caused by natural changes such as the sun's activities and volcanic eruptions, but human activities mainly cause it.

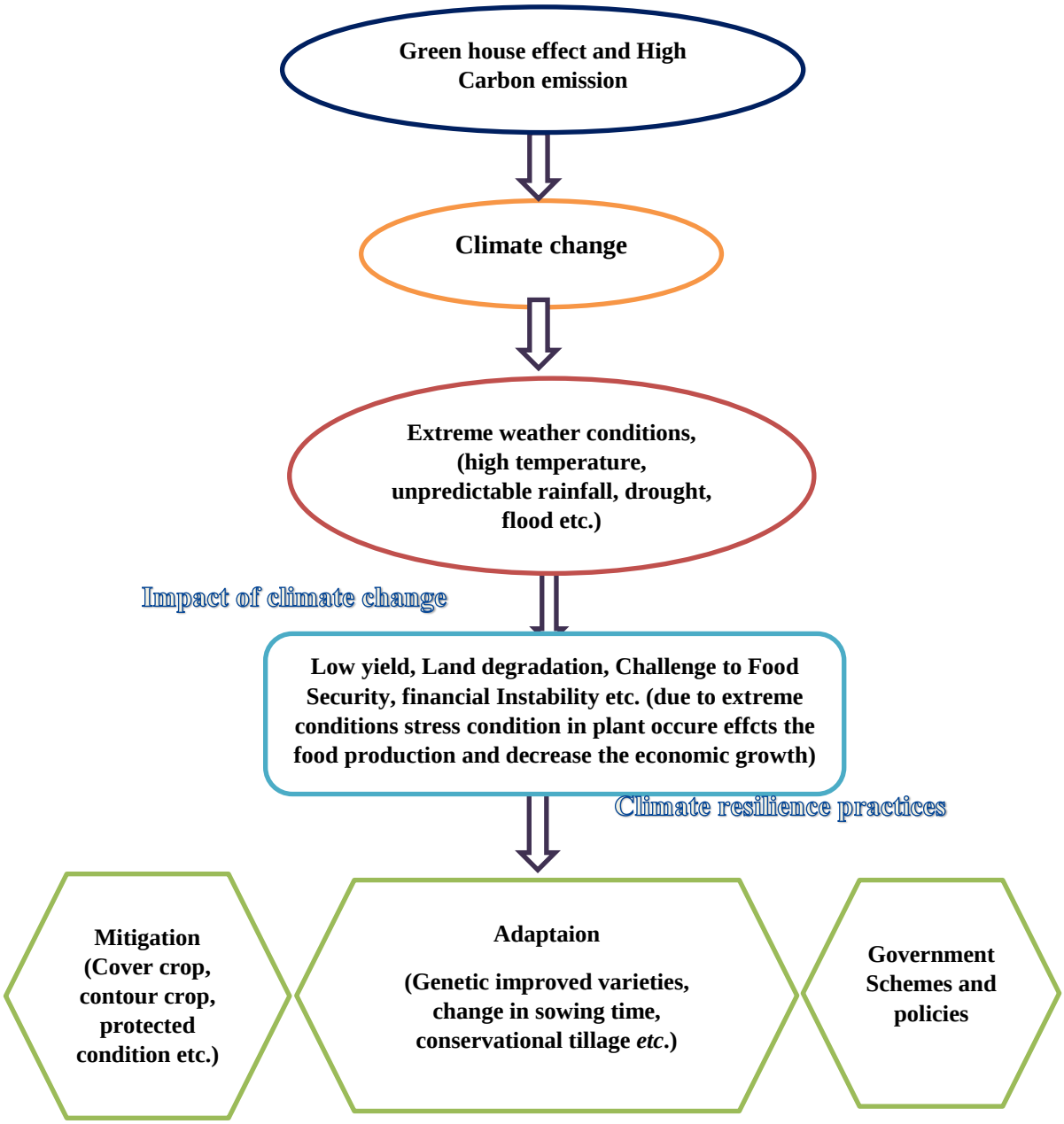
Most people think that climate change mainly refers to an increase in temperature. Still, it serves many consequences, including intense drought, water scarcity, rising sea levels, flooding, melting polar ice, declining biodiversity, *etc*. Climate change is a concern that is developed with the increasing concentration of greenhouse gases (CO_2, Methane and $NO_{2)}$ in the atmosphere, which makes a blanket and covers the atmosphere, causing incident rays to pass through as they are short in wavelength but trap the rays which reflect back in long wavelength that cause an increase in the temperature. The globally increased temperature due to the greenhouse effect causes some challenges like high risk of drought, extreme or no rainfall, floods and extreme heat.

Impact of climate change on the horticulture crops

As we know that horticulture crops are temperature sensitive and require specific temperature during different stages of their lifecycle. Due to climate change, significant challenges arise in the cultivation of horticultural crops. Climate is severely affecting fruit, vegetable, medicinal, and aromatic plant crops, which are responsible for the reduction in production and yield. Increasing temperature directly affects physiological activity, enzymatic activity, respiration, and photosynthesis, causing alteration in sugars, organic acids, antioxidants, minerals, and overall quality. Increasing CO2 level reduces evapotranspiration and thus increases the plant's water use efficiency (Chachar *et al.*, 2023)**.** In fruit crops due to, stress brought up by the fluctuation in the climatic conditions influences the production and income of the farmer. Due to the perennial nature of fruit crops, it requires high investment to establish the orchard, but due to climate change, farmers are shifting to other crops, which is causing a drastic loss in income. Since the long spell of drought, low precipitation, and less snowfall during winter are farmers' main concerns, most fruit crops grown in temperate regions require vernalization to change into a reproductive phase and produce fruit. Apple cultivation is adversely affected by the shift in the pattern of snowfall. Mango and guava are tropical fruits suitable for high temperatures, but the extreme weather phenomenon of hot and cold wave conditions impacts the flowering. Vegetable crops are succulent in nature and are highly vulnerable to high temperatures. In vegetable crops like cabbage and cauliflower, curd and head formation are affected by the fluctuation in temperature (Arimi, 2021). Temperature causes many physiological disorders to the Cole crops, which deteriorate their quality and reduce the price in the market.

It causes a shift in the crop sowing time and causes early maturity and low yield. In photosensitive crops like onion, it causes early maturity of bulbs with inferior size; it affects the tuberisation process in potatoes, pigment development in tomatoes, poor pollination and bolting, *etc*.

Fig.1. Impact of Climate change and climate resilience practices



It is defined as the ability of the system and its components to forecast, captivate, accommodate, or recover from the consequences of a hazardous event properly and effectively. This includes the assurance of maintaining the fundamental structures and functions secure, preserved, and improved (Morecroft *et al*., 2019). Climate resilience is related to coping with and managing climate change's impact and preventing its worsening probability. It is referred to as the socio-ecological system's ability to withhold external stress due to climate change while conserving its functionality. It has the capacity to withstand the shocks and immediately return to its normal state when factors get better.

It is a comprehensive and systematic approach toward climate-smart horticulture and plays a vital role in preventing the harmful effects of climate change (Sarma *et al.*, 2024). This process includes unifying cutting-edge technology, sustainable and eco-friendly farming practices, and different methods of increasing resource use efficiency, reducing harmful ecological footprints with a guaranteed sustainable horticulture production network.

In simple terms, this practice is defined as "to bounce back" given by Francis Bacon in 17th century. Resilience is the relative approach toward threat and vulnerability. It represents the risk of losing something according to the vulnerability.

Adaptation and Mitigation of climate change:

The effect of climate change depends not only on the climate change but also on the ability to adapt towards the change. Adaptation is the practice of changing for the betterment of self-being and surroundings. It is an evolutionary process where an organism develops the ability to change its habitat and surroundings (Karagatiya *et al.*, 2023). It depends on the vulnerability of a particular crop toward its agroecological region and the growing season; the desired adaptation strategy is implemented or developed for the establishment of crops in adverse conditions (Singh *et al*., 2013). It makes plants able to withstand the effects of climate change and increases their survival rate. It includes implementing modified crop management practices, water use efficiency, resistant rootstocks, and varieties to reduce the impact of climate change and increase plant adaptability. Changes in the time of sowing are also beneficial in tackling the increase in temperature and water stress.

Mitigation strategies are simply based on reducing greenhouse gases and their harmful effect. It means reducing the concentration of heat-trapping greenhouse gases in order to reduce the emission and enhance sink (Fawzy *et al.*, 2020). It includes different measures such as improving energy efficiency and conservation, using hydro and renewable energy, afforestation and preservation of forests, and using electronic vehicles and tools that do not emit harmful gases. It reduces the negative impact of climate change on crops and the environment, and alternative methods are sought to minimize the impact (Singh *et al.*,

2013). Mitigation focuses on the leading cause of the problem and provides a solution by eliminating the long-term consequences. It includes improving cultivation practices that cause the emission of greenhouse gases by implementing the sustainable approach and improving field management practices such as minimum tillage, zero tillage, integrated nutrient management, *etc*.

Strategic Approach for Climate Resilience Horticulture Practice:

Development of heat resistance and drought tolerance varieties: Heat and drought tolerance are the most essential traits for horticulture crop production. Heat and drought directly affect the physiology of crops, plant growth, yield and quality (Jain *et al.*, 2024). It involves the reproductive stage, which causes delays and decreases in flower sets and fruit sets, which decrease the overall productivity of the crop. It reduces the photosynthesis rate of the plant and causes severe water loss, which reduces the plant's survival rate and later causes wilting and death of the plant in succulent vegetable and fruit crops.

Development Salt tolerance varieties: Soil salinity is one of the significant problems that hinders the ability of plants to absorb water due to the high concentration of salt present in the soil, which develops osmotic stress conditions that make plant water deficient. It causes stunted plant growth, wilting, and death of plants, making them unable to draw water from the soil. The development of salt tolerance and resistance varieties can withstand these challenges and increase the adaptability of crops toward salt tolerance.

Irrigation (Micro-irrigation or Drip irrigation) and water stress management: Drip or trickle irrigation involves a whole systematic unit. It consists of emitters, valves, pipes, and a drip line near the plant roots, and it directly provides water to the root area drop by drop. It is the most efficient irrigation method, with an efficiency of 90% and reduces water loss. In this method, fertilizer is also provided along with irrigation water through drip lines, so it is an efficient method that provides nutrients directly to the plant and increases yield and productivity. It significantly reduces water wastage and provides precise application of water to provide yield stability. It also reduces water stress by delivering the water directly to the root zone, leading to healthier crop production and yield.

Soil management practice: Soil management is a significant factor that plays an essential role in climate resilience; degradation of land by nutrient mining, imbalanced nutrient application, inadequate and imbalanced pesticide and herbicide application, *etc*., are the causes that cause soil deterioration and reduce the quality of soil. Mulching and conservation tillage soil health, structure, water holding capacity *etc.* can be enhanced. Applying balanced nutrients and other chemicals with an integrated approach can reduce its harmful impact and help in mitigation of harmful effect. Mulching protects soil from erosion and reduces evapotranspiration and improves the soil structure. Adding organic

matter increases the soil's water-holding capacity, improving the soil structure and microbial growth. To increase development, organic mulching is advisable for the tomato, bottle gourd, capsicum, *etc*. These practices reduce the emission of harmful gases and can potentially decrease the carbon emission of different cultivation practices.

Technology Used for Climate-Resilient Horticulture Practices:

Precision Horticulture: precision farming is the technology that provides adaptability against climate change. It includes resource efficiency by using a specific approach that ensures utilization of inputs and reduces resource waste by ensuring each plant receives the precise amount required for optimal growth. It provides early detection of potential threats due to weather phenomena that impact the crops. It gives real-time data to adjust cultivation to changing environmental conditions.

Controlled Cultivation Practice:

It includes practices such as controlled environment conditions, vertical farming, hydroponics, aeroponics and aquaponics. These technologies provide several advantages over traditional farming (Spaldon *et al*., 2015).

Controlled Environment condition: It provides plants with controlled conditions throughout their life cycle, adequate nutrient supply, and other essential key aspects such as light, temperature, humidity, *etc*. It minimizes the impact of weather hazards that can deteriorate the crop, such as winds, hailstorms, drought, floods and heat waves (Gruda *et al*., 2019). It mitigates the effect of seasonal variations and provides round-the-year production. Greenhouse or polyhouse crops are grown in controlled conditions with active heating and cooling systems. The heating system traps solar radiation and increases the temperature to maintain night temperature; thermal blankets are used. It is most effective for cold regions with low temperatures and crops grown in well-equipped polyhouse. The cooling system consists of a wide range of technologies, including forced ventilation, fan pad systems, foggers, mists, and evaporative cooling systems, which reduce the heat and provide crops with proper growing conditions (Kamali & Dhivya, 2024).

Vertical farming: It is a sustainable and resilient approach regarding climate change. It is the system of growing vegetable crops in a stacked layer approach for efficient use of space. In this technique we can optimize a larger area and grow more vegetables and fruits such as strawberries, lettuce, Chinese cabbage and parsley, *etc*. It includes soilless cultivation practices such as Hydroponics, Aeroponics and Aquaponics.

Hydroponics: It is a soilless cultivation practice in which water is used as growing media and crops are grown in the nutrient medium. Nutrients are mixed with water, and the unit is arranged in such a way that nutrients continuously flow and plant roots are dipped in it. It reduces water wastage and ensures that nutrients are provided

precisely to the units. It protects the soil from exploitation, conserves it, and provides resilience to climate change.

Aeroponics: This is the process of growing plants in an air or mist environment without soil and nutrients are provided by spraying of mist to the root zone (Kuddus *et al*., 2021). It contributes to climate resilience by providing effective measures such as reducing water and nutrient use and optimizing chemicals and nutrients. It is used to grow high-value vegetables efficiently and generate high income.

Aquaponics: It is a comprehensive approach to cultivating fish with crop production. In this method, a fish tank is installed at the base of the hydroponic unit, and water continuously flows into the system. The purified water from the plants is returned to the fish tank and the waste of fish is used as the nutritive feed for plants. It is an integrated approach to growing fish and cultivating crops together for better utilization of resources and reducing scarcity.

Projects Launched By Government For Implementation of Climate Resilience Measures:

National Mission on Sustainable Agriculture (NMSA) was initiated in 2008 in the Prime Minister's National Action Plan. It aims to permit the country to adopt a climate change strategy. It aims to make agriculture more productive and sustainable for high yield and productivity, leading to high-income generation. It focuses on climate resilience by promoting a localized integrated farming system, soil and moisture conservation measures, *etc*., to tackle extreme conditions.

National Action Plan on Climate Change (NAPCC), launched in 2008, aims to evolve and implement strategies to make Indian agriculture more resilient to climate change. It focuses on mitigation and adaptation measures to tackle climate change and aims to reduce greenhouse gas emissions and carbon prints. It includes eight missions to minimize the harmful environmental effects and build climate resilience.

1. National Solar mission
2. National Mission for Enhanced Energy Efficiency
3. National Mission on Sustainable Habitat
4. National Water Mission
5. National Mission on Agriculture Adaptation
6. National Mission on Green India
7. National Mission on Strategic Knowledge for Climate Change
8. National Mission for Sustainable Himalayan Ecosystem

National Innovation on Climate Resilient Agriculture (NICRA) This project is dedicated to improving agriculture by developing resilient cultivation practices. This project was launched in 2011, considering the growing effect of climate change and its fatal impact on the environment and human health (Mohokar *et al.*, 2019). This project aims to develop aim to promote climate resilience agriculture technology to the districts and particular regions by KVKs and societies.

Conclusion

Climate resilience in horticulture is a very encouraging and beneficial practice in solving the problem, which can cause a serious threat to horticulture production. The most effective measures for climate resilience are mitigation and adaptation, which use different approaches such as conservational tillage, mulching, vertical farming, hydroponics, aeroponics, variety

development, and modification in cultivation practice to increase crop adaptability. This is the most necessary approach toward agriculture to mitigate the impact of climate change. If the greenhouse gas emission continues and controlled measures are not implemented, extreme climate change will adversely affect the environment, horticulture production, and human health. It requires the collaboration of the government and corporate sector, and each person must look after this to ensure a safe future. The government has launched many schemes and plans to encourage the adaptation of climate resilience practices to reduce the risks generated by climate change.

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