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*Review Article*

# Effect of Climate Change on Vegetable Cultivation - A Review

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**ABSTRACT**

*The world's population is growing at an alarming rate, and by 2050, it is predicted to reach almost six billion people. Increased hunger and malnutrition are complicated concerns for many countries, especially those with limited resources. Feeding the world's hungry people necessitates a large quantity of food and high food quality. Vegetables are essential in human nutrition because they are the only nutrients, vitamins, and minerals. They also provide an excellent return on investment for the farmer because they sell for a more fantastic price in the market. Climate change, including global warming, changes in seasonal and monsoon patterns, and biotic and abiotic factors, is impacting these crops, just as they are on other crops. Crop failures, yield shortages, quality reductions, and increased pest and disease problems are all typical of changing climatic conditions, making vegetable farming unprofitable. Many physiological systems and enzymatic activity are temperatures sensitive; therefore, they will be significantly impacted. Drought and salinity are two significant repercussions of rising temperatures, which wreak havoc on vegetable cultivation. Increased CO2 fertilization may enhance crop yields initially, but this effect fades. Anthropogenic air pollutants such as CO2, CH4, and CFCs contribute to global warming, while nitrogen and sulphur dioxides deplete the ozone layer, penetrating dangerous U.V. rays. Climate change influences pest and disease occurrences, host-pathogen interactions, insect distribution and ecology, time of appearance, migration to new sites, and overwintering capabilities, all severe setbacks to vegetable farming. Because of its precise climatic requirements for several physiological processes, the potato is the most vulnerable to climate change.*

***Keywords:*** *Climate change, Vegetables, Quality, Pest and diseases.*

## INTRODUCTION

Climate change can be defined as a shift in the mean of several climatic parameters such as temperature, precipitation, relative humidity, atmospheric gas composition, and changes in attributes over time and throughout a broader geographical area.

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Any change in climate over time, whether caused by natural variability or human activity, is referred to as climate change. According to Schneider et al. (2007), the degree to which any system is vulnerable to climate change is the degree to which that system is sensitive to and unable to sustain the harmful effects of climate change. They also explained risk as a notion that reflects uncertainty in the underlying processes of climate change, exposure, impacts, and adaptation by combining the size of the effects with the chance of its occurrence. Changes in the climate are already occurring as a result of manufacturing activities such as industrialization, deforestation, and automobiles, among others, which will once again be damaging to life (Rakshit et al., 2009). Temperature swings, increased soil salinity, waterlogging, high atmospheric CO2 concentrations, and U.V. radiation are all examples of climate change. The increased amount of greenhouse gases such as CO2 and CH4 in the atmosphere (Table 1) causes global warming, also known as the greenhouse effect. From 1901 (24.23°C) to 2012 (24.69°C), India's mean annual temperature has risen by 0.46°C over the last 111 years (Data Portal India, 2013). The average global surface temperature over land and water has risen from 13.68°C in 1881-90 to 14.47°C in 2001-10. (WMO, 2013). By the last decade of the twenty-first century, the globally averaged surface temperature is anticipated to climb from 1.1°C to 6.4°C (Minaxi et al., 2011). The change in mean decadal temperature in India and the rest of the world, respectively. This rise in temperature will affect rainfall timing and amount, water availability, wind patterns, and the occurrence of weather extremes such as droughts, heatwaves, floods or storms, changes in ocean currents, acidification, forest fires and hastens the rate of ozone depletion (Minaxi et al., 2011; & Kumar, 2012).

**Climate change vs Vegetables**

Vegetables are classified as protective foods because they provide the human body with important nutrients, vitamins, and minerals and are the greatest way to overcome micronutrient shortages. Vegetable output has increased globally in the last quarter-century, and global vegetable trade now exceeds grain trade-in value. In Asia, the best yields are found in the east, where the temperature is mostly temperate or sub-temperate. After China (22.5 t/ha), India is the second greatest producer of vegetables (17.3 t/ha). Vegetable production in India has increased 2.5 times in the last two decades, from 58.5 mt in 1991-92 to 146.5 mt in 2010-11. (Kumar et al., 2011). High temperatures and limited soil moisture are the main causes of low yields in vegetables because they greatly affect several physiological and biochemical processes such as reduced photosynthesis, altered metabolism and enzymatic activity, thermal injury to the tissues, reduced pollination and fruit set, and so on, which will be amplified by climate change.

Climate change has had a significant impact on vegetable production. Crop failures, yield shortages, quality reductions, and increased pest and disease problems are typical of changing climatic conditions, making vegetable farming unprofitable. As a result, the availability of nutrient sources in the human diet is questioned. The summer monsoon in South Asia will be delayed and less predictable, and temperature rises will be most extreme during the winter season (Lal et al., 2001). Water shortages come from monsoon failure, resulting in lower-than-average crop yields. Drought-prone areas like southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, Orissa, Gujarat, and Rajasthan are most affected. In Andhra Pradesh, Tamil Nadu, and Karnataka, high heat and insufficient rainfall during sowing and excessive rainfall during harvesting cause serious crop losses. The maximum and minimum temperature (1960-2003) analysis for the northwest region of India revealed that the minimum temperature is increasing at annual, kharif, and rabi season time scales, according to the Network Project on Climate Change (Impact, Adaptation, and Vulnerability of Indian Agriculture to Climate Change). During rabi, the minimum temperature rises at a significantly faster rate than during kharif. Maximum temperatures increased on annual, kharif, and rabi time periods. However, a very fast rise was noted from 2000 onwards, with major negative rainfall patterns in Madhya Pradesh, Chhattisgarh, and Rajasthan. (http://www.crida.in/Climate%20change/ network.htm).

Climate change affects pest and disease incidence, host-pathogen interactions, insect distribution and ecology, time of appearance, migration to new sites, overwintering capacity, and physiological and biochemical alterations. Plant diseases are strongly influenced by the environment that surrounds the host and pathogen, and changes in components can affect host vulnerability and, as a result, the host-parasite interaction (Khan, 2012). Climate change has the potential to influence host physiology and resistance and pathogen stages and rates of development (Coakley et al., 1999). Temperature, rainfall, humidity, radiation, and dew can all affect the growth and spread of fungus and bacteria, according to Neumeister (2010). Air pollution, particularly ozone and UV-B radiation, and nutrient availability, are other major elements that influence plant diseases. The following summarises Boonekamp's (2012) findings on the effects of climate change on plant-disease interactions: 1. Higher temperatures will speed the life cycle of many dangerous fungi, resulting in a faster rate of multiplication and, as a result, an increase in infection pressure. 2. Diseases with long generations will be able to infect crops at a later stage of growth than they are now. 3. The expression of resistance genes in the host plant and the efficacy may decrease dramatically with climate change. Selection for more aggressive races or strains occurs within pathogen populations as the number of generations or multiplication rates of the pathogen increases, and when such selected races or strains find a host with compromised resistance, they become virulent, leading to unprecedented opportunities for disease epidemics. 4. When cropping genetic variety is minimal over a large cropping region, and a new or adapted strain becomes prevalent in the pathogen population, the consequences can be catastrophic.

Several important effects of various climatic factors on vegetable growth and development and the incidence of pests and diseases have been summarized below.

**Temperature**

Because many plant physiological, biochemical, and metabolic activities are temperature dependent, fluctuations in mean daily maximum and lowest temperatures are the principal effects of climate change that negatively affect vegetable production. Potato is the world's fourth most significant non-cereal basic food. Because potato tuber formation and flowering require precise temperature and day duration requirements, it is the most vulnerable crop. Singh et al. (2009) previously investigated the impact of climate change on potato output in India. In all of India's potato-growing states, productivity is predicted to drop. If no specific techniques are adopted, Luck et al. (2010) predicted a 16 per cent drop in potato tuber yield in West Bengal by 2050. However, they did recommend planting the potato crop at a new ideal date of mid-November to reduce production losses by up to 8%.

Increased temperature favours potato cultivation by extending the crop growing season in high altitudes and temperate regions of the world like Europe, Russia, India, Himalayan and other mountain regions, and frost-prone states like Haryana and Punjab. Still, it disadvantages potato production by shortening the growing season in subtropical plains like West Bengal and Bihar during the winter season (Singh, 2010). The processing sector prefers potato tubers with high starch content. At low temperatures, starch is converted to sugar, which results in browning owing to sugar charring, reducing the processing industry's demand for chips. This leads to higher post-harvest losses than the current level, which is estimated to be between 40 and 50 per cent. This is a prevalent concern in locations where nighttime temperatures drop below the recommended level during the winter season (Singh, 2010).

When determining the marketability of a tomato, the colour of the fruit is very important. The ideal temperature for lycopene pigment formation in tomatoes is between 25 and 30°C. Lycopene begins to degrade at temperatures over 27°C and is totally destroyed at temperatures above 40°C. Pollination and fruit set in tomatoes are also affected by temperatures above 25°C (Kalloo et al., 2001). Lurie et al. (1996) stated that high-temperature limits were ripening by preventing the buildup of ripening-related m-RNAs, which prevents continuous protein synthesis, such as ethylene generation, and lycopene accumulation, and cell-wall breakdown. Fruit set is inhibited in pepper plants when they are exposed to high temperatures after pollination (Erickson & Markhart 2002).

Cucumber and melon seed germination is considerably reduced at 42 and 45 degrees Celsius, respectively, and watermelon, summer squash, winter squash, and pumpkin seed germination is not possible at 42 °C (Kurtar, 2010). Warm, humid weather promotes vegetative development and reduces female flower production in cucurbitaceous vegetables such as ash gourd, bottle gourd, and pumpkin, resulting in low yields (Singh, 2010). French bean productivity is reduced by moisture stress in April and May, as well as heavy rain during the flowering and fruiting stages (June-July) (Singh, 2010). High temperatures in tomatoes can result in severe productivity losses due to lower fruit settings, smaller sizes, and poor quality fruits. The optimal daily mean temperature for the tomato fruit set has been recorded at 21-24°C. In tomatoes, the preanthesis is more sensitive. Pepper fruit set is inhibited by high temperatures after pollination, demonstrating that the fertilization mechanism is sensitive. The temperature affects cucumber sex expression. Low temperatures encourage the creation of female flowers, which is ideal, while high temperatures encourage the production of more male flowers, which is undesirable. Because of the high temperature, the onion's lifespan is limited, resulting in lower yields.

High temperatures induce poor seed germination in okra during the spring and summer seasons. Okra flower drop has been observed at temperatures above 42°C (Dhankhar & Mishra, 2001); in the case of the French bean, blossom abscission and ovule abortion occur at temperatures exceeding 35°C (Prabhakara et al., 2001).

Increased temperature causes insect species to migrate to higher latitudes, whereas greater temperatures in the tropics may harm specific pest species. As reviewed by Das et al. (2011), high atmospheric temperature increases insect developmental and oviposition rates, insect outbreaks, and the introduction of invasive species, while it decreases the effectiveness of insect bio-control by fungi, the reliability of economic threshold levels, insect diversity in ecosystems, and parasitism. Yukawa (2008) observed that Nezara viridula, a tropical and subtropical agricultural pest, is steadily spreading northward in southwestern Japan, probably as a result of global warming, and is displacing the more temperate Nezara antennata (FAO, 2008).

Cauliflower thrives in temperatures ranging from 15 to 25 degrees Celsius, with high humidity. While certain cultivars have evolved to temperatures beyond 300°F, the majority of kids are sensitive to higher temperatures and curd commencement is delayed. Increases in onion temperature above 400°C reduced bulb size, while increases of roughly 3°C above 38°C reduced yield by 19%. Warmer temperatures limit the time it takes for plants to grow, resulting in poorer crop yields. High temperature lowered marketable grade tuber yield by 10-20%, and frost damage reduced tuber output by 10-50%, depending on intensity and stage of occurrence. Temperatures above 20°C during the winter have an impact on the cultivation of seasonal button mushrooms and lead to an increase in the occurrence of diseases.

Because of their high-temperature optimum and frost sensitivity, soil-borne pathogens such as Sclerotium rolfsii and Macrophomina phaseolina do not occur in temperate areas, despite their large host range (Termorshuizen, 2008). Because of the reduction of frost, higher temperatures generate faster disease cycles in airborne infections and enhance their survivability (Termorshuizen, 2008 & Boonekamp, 2012). Due to the early appearance and increased number of insect vectors of viral diseases caused by the increase in temperature during the winter, viral diseases of crops such as potato and sugarbeet have increased (Harrington et al., 1995).

**Drought and salinity**

The most significant side effects of global warming are drought and salinity. Drought has a negative impact on the germination of seeds in vegetable crops like onion and okra, as well as the sprouting of tubers in potatoes (Arora et al., 1987). Drought is a serious problem for potatoes. Reduced tuber yields can also be caused by moderate water stress (Jefferies & Mackerron, 1993).

Drought circumstances reduce the water content of succulent leaves, which are commercial items in leafy crops like amaranthus, palak, and spinach, lowering their quality (AVRDC, 1990). Drought raises salt levels in the soil and inhibits the reverse osmosis process, which causes water loss from plant cells. This causes greater water loss in plant cells as well as the suppression of various physiological and biochemical processes such as photosynthesis and respiration, lowering vegetable output (Pena & Hughes, 2007).

Salt stress causes turgor loss, wilting, leaf abscission, decreased photosynthesis and respiration, cellular integrity loss, tissue necrosis, and eventually plant death (Cheeseman, 1988). Onions are highly sensitive to saline soils, whilst cucumber, eggplant, pepper, and tomato are somewhat vulnerable (Pena & Huges, 2007). In cabbage, salinity reduces germination percentage, germination rate, root and shoot length, as well as fresh root and shoot weight (Jamil & Rha, 2004). In chilli, salinity decreases dry matter production, leaf area, relative growth rate, and net assimilation rate while increasing the leaf area ratio. Salinity has a greater impact on the number of fruits per plant than on the weight of individual fruits (Lopez et al., 2011). All cucurbits lose fresh and dry weight when exposed to high salt levels. A decrease in relative water content and total chlorophyll content is linked to these changes (Baysal et al., 2004).

In bean plants, salt stress causes growth and photosynthetic activity to be suppressed, as well as changes in stomatal conductance, quantity, and size. In salt-affected bean plants, it lowers transpiration and the cell water potential (Kaymakanov et al., 2008). High saline levels in soil and irrigation water have been shown to influence a variety of physiological and metabolic processes, resulting in a reduction in cell development (Gama et al., 2007). When accessible moisture is scarce, certain diseases are less severe. Reduced root growth under moisture stress reduces the risk of infection by soil-borne microorganisms by reducing the probability of roots coming into touch with pathogen propagules in the soil (Pertot et al., 2012).

**Flooding**

The majority of vegetable crops are particularly susceptible to flooding, and genetic diversity in this trait is limited. Flooded crops, particularly tomato plants, collect endogenous ethylene, which harms the plants (Drew, 1979). Low oxygen levels cause the roots to produce more of an ethylene precursor called 1-aminocyclopropane-1- carboxylic acid (ACC). With rising temperatures, the severity of flooding symptoms rises; rapid withering and mortality of tomato plants is common after a brief time of flooding at high temperatures (Kuo et al., 1982).

**Other stress factors**

**CO2 and Relative Humidity**

Greenhouse gas concentrations, such as $CO_2$ and $CH_4$, are steadily rising in the atmosphere due to increased anthropogenic activities. They contribute to global warming and have a direct impact on plant growth and development. Potato plants cultivated in high $CO_2$ environments may have higher photosynthetic rates initially, but as the $CO_2$ concentration rises, the photosynthetic rates decrease (Burke et al., 2001). The high $CO_2$ content in the atmosphere prevents tomato fruit from ripening. This inhibition is caused by the repression of ripening-related genes, which is most likely connected to the stress effect of elevated $CO_2$ (Rothan et al., 1997).

The presence of pests and diseases can be influenced by relative humidity and $CO_2$ (Hamilton et al., 2005). Furthermore, insects prefer lower-nitrogen-content leaves in order to obtain more nitrogen for their metabolism (Hunter, 2001). As reviewed by Das et al. (2011), increased predation by predators, the effect of foliar application of Bt., carbon-based plant defence, and decreased insect development rates are the negative effects of high atmospheric $CO^2$. The positive effects are increased predation by predators, the effect of foliar application of Bt., carbon-based plant defence, and decreased insect development rates. Early in the season, soybeans planted under a higher $CO_2$ environment suffered 57 per cent greater insect damage than those grown in today's climate, necessitating an insecticide treatment to keep the experiment going. Measured increases in the amounts of simple sugars in the soybean leaves are considered to have triggered the increased insect feeding (Hamilton et al., 2005).

Increased $CO_2$ levels may enhance the size and density of C3 plant canopy, resulting in more biomass and a substantially higher microclimate relative humidity. When these conditions are met by warmer temperatures in winter, the slower breakdown rate caused by increased biomass as a result of greater $CO_2$ will likely boost pathogen survivability and aid in overwintering. Plant diseases such as rusts, powdery mildews, leaf spots, and blights are likely to spread as a result of this (Das et al., 2011).

**Air pollutants and U.V. radiation**

Pollutants in the air, such as $SO_2$, $O_3$, and acid rain, have direct effects on plant tissue and pathogens. According to numerous findings, plants respond differently to foliar infections when exposed to contaminated air. In addition, root-attacking pathogens like plant nematodes may be impacted by pollutant-mediated host effects. Higher levels of $SO_2$ and $O_3$ (200-300 ppb) prevented the germination, invasion, and sporulation of plant pathogenic fungi, and as a result, plants in stressed areas suffered milder illnesses. Lower amounts of air pollutants, such as 50-100 ppb, can function as a predisposing agent and aggravate plant diseases. By increasing spore germination and fungus and egg invasion, $SO_2$ and $O_3$ at 50-100 ppb exacerbated the severity of fungal and nematode illnesses (Khan, 2012).

Tomatoes, cabbage, potatoes, and sugar beets are more vulnerable to U.V. radiation than other vegetables (Pena & Huges, 2007). External effects such as glazing and bronzing are produced when the leaves of the French bean are exposed to ultraviolet radiation, and the sensitivity to virus infection is increased. Increased UV-B exposure reduces dry weight, leaf area, and plant height, as well as inhibiting tomato growth by reducing the photosynthetic area (Hao et al., 1997).

## CONCLUSION

Though climate change is a continual process, it had become apparent in the agricultural area in recent years, when it began to have a substantial and long-term impact on crop productivity. Although the causes of climate change are unknown at this time, existing evidence suggests that anthropogenic activities such as industrialization and mechanization may play a role to some extent. The impacts of increased temperature caused by global warming on crop plants are the most significant of all climate change effects. It is also to blame for other pressures such as drought or moisture stress, salinity, floods, and waterlogging in coastal areas when polar ice melts and sea levels rise. CO2 is a major component of greenhouse gases, which are responsible for global warming, and it has a significant impact on growth and development, as well as pests and illnesses of vegetable crops. As a result, it is obvious that climate change will have a greater impact on global food security in the near future.

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