Review Article

Climate Change Impact on Insect Population in Vegetable Crops: A review

ABSTRACT

India is one of the largest countries of the world with unique landscaping making it a distinct geographical entity and one of the mega diversity centers of the world. Among climate change can have a significant impact on insect populations in vegetable crops. Changes in temperature and precipitation patterns can alter the distribution and abundance of insect species, affecting pest pressure and crop damage. Additionally, warmer temperatures can lead to faster insect development and increased reproductive rates. Farmers and researchers need to monitor these changes and develop strategies to mitigate the potential negative effects on vegetable crops. In response to climate change, whiteflies may exhibit shifts in their distribution patterns, population sizes, and behavior. They may also evolve certain traits that help them better survive in warmer or more variable climates.

Key words: Temperature, rainfall, humidity, *Thrips tabaci* , Okra, red spider mite, Jassids, *Earis vitella*, *Helicoverpa armigera*, Chilli, thrips Onion, Bitter gourd, Bottle gourd, Cucumber, Cabbage , Cauliflower.

INTRODUCTION

Climate Change reasserted that the atmospheric concentrations of CO2, methane, and nitrous oxide greenhouse gases have increased markedly since **1750**[1]. Most of chewing insects exhibit compensatory increase in food consumption. Tomato meets the dietary nutrient and antioxidant requirements of diverse populations. Being a C3 crop and an important vegetable, it is likely to be influenced by increased CO2 concentrations under climate change situation. In India, *H. armigera* incidence is common on cotton, pigeon pea, chickpea, sunflower, tomato, sorghum, millets, okra, and corn **(Manjunath *et al*., 1989; Sharma 2001).** Higher *H. armigera* moth activity and the capture of more moths have resulted from increased temperatures (**Maelzer and Zalucki, 1999; Maelzer *et al*., 1996).** Future climate years along with higher temperatures predicted one to two additional generations of *H. armigera* with reduced generation time **(Srinivasa Rao *et al*., 2016)**. These pests, once restrained by nature's rhythms, are seizing the opportunity afforded by the changing climate to flourish, resulting in devastating consequences for crop yields and, by extension, the well-being of communities dependent on agriculture. Studies unravel the intricate connection between climate change, the alarming rise of pest diseases, and its ripple effects on agriculture, emphasizing their collective importance in shaping the future of farming and livelihoods **(Skendzic *et al*., 2021)**. Whitefies (Hemiptera: Aleyrodidae) are important insect pests causing serious damage to plants and transmitting hundreds of plant viruses. Climate change is expected to influence life history and trophic interactions among plants, whiteflies and their natural enemies **Oluwatosin Z. Aregbesola *et al*., 2018)**. Climatic change is affecting agricultural and natural ecosystems and directly affects the development, reproduction, survival, population dynamics, potential distribution and abundance of whitefly species **Muniz and Nomb ela 2001; Bonato *et al*., 2007; Bellotti *et al*., 2012; Gilioli *et al*., 2014)**. Insect pest infestations on tomatoes are one of the prime reasons for the low productivity of this crop **Silva *et al*., 2011).** Onion thrips (*Thrips tabaci* Lindeman; Thysanoptera: Thripidae) are a polyphagous pest that causes serious damage on vegetables and ornamentals all over the world **Murai 2000**).Climate change can indeed have an impact on insect populations, including the diamondback moth in cabbage. Warmer temperatures and changing weather patterns can affect the life cycle, behavior, and distribution of insects. In the case of the diamondback moth, which is a common pest in cabbage crops, warmer temperatures may lead to increased reproduction rates and longer breeding seasons, potentially causing greater damage to cabbage crops. It's important for farmers and researchers to monitor these changes and develop strategies to mitigate the impact of climate change on insect populations in order to protect agricultural crops. The extent of yield loss caused by the pest to cucurbitaceous vegetables ranges from 30 - 100%, depending upon cucurbit species and the season **Dhillon *et al*., 2005**)

Throughout history, human population growth has been accompanied by many changes in everyday life, culture, technology, science, the economy, and agricultural production. Agricultural production has also undergone many major changes agricultural revolutions which have influenced by the development of civilization, technology, and general human advancement. However, the exceptional population growth in the last 100 years has had many undesirable consequences that (along with changes in environmental conditions) impact the security of the food supply. The growing world population has rising demands for crop production and accordingly, by 2050, global agricultural production will very likely need to be doubled to meet that kind of increasing demand. Among the locations, the incidence of *H. armigera* and damage caused by its infestation was observed to be higher in lower altitudes as compared to higher altitude locations.

INSECT RESPONSE TO CLIMATE CHANGE

Insects are likely to be most affected by climate change because environmental factors have a strong influence on the development, reproduction, and survival of insect pests and their natural enemies **(Bale et al. 2002).**

Global warming will lead to faster development of immature stages, and adults will emerge much earlier than before. Observed responses include early adult emergence and an increase in the length of the flight period. Changes in butterfly phenology have been reported in Europe **(Roy and Sparks 2000; Stefanescu et al. 2003),**

CLIMATE CHANGE AND ARTHROPOD DIVERSITY

TABLE 1 Species diversity among different groups of organisms.

Organisms	**Number of Species**
Protoctists (algae, protozoa, etc.	) 80, 000
Bacteria	4, 000
Fungi	72, 000
Plants	270, 000
Invertebrates (arthropods: insects, spiders, mites, etc.)	1, 272, 000
Vertebrates	52, 000
Total number of described species	1, 750, 000

Possible unknown species	14, 000, 000

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1. Climate change and pest status

Agro-ecosystem environment is largely governed by communication between abiotic (temperature, humidity, rainfall, soil factors, pollutants etc.) and biotic (crop- plants, weeds, insect-pests, pathogens and nematodes etc.) factors. The abiotic stress factors modulate the effects of biotic stresses and are most harmful when arise in combination

2. Climate under Change 1950-1975, 1976-2000 and 2001-2024

During the period of 1950-1975, there were significant changes in climate patterns which could have impacted the population dynamics of pests like *Plutella xylostella* in cabbage crops. The warming temperatures and altered precipitation levels during this time may have influenced the behavior and distribution of this particular pest species. It is important to consider these environmental factors when studying the prevalence of *Plutella xylostella* in cabbage and cauliflower during the mid-20th century.
Spiralling whitefly *Aleurodius disperses* during the period of first reported in India 1995

Climate under Change during period 2001-2024

Forecasts of climate Change are uncertain, especially multi-decadal forecasts and regional climate change prediction.

2.1 Impact of Climate Change on Crop Production

Changes in temperature, precipitation patterns, and extreme weather events can all affect the growth and yield of crops. For example, rising temperatures can lead to heat stress in crops, while changes in precipitation patterns can result in droughts or floods. These factors can reduce crop yields, decrease food security, and ultimately impact global food supply. It's important for farmers and policymakers to adapt to these changes and implement sustainable practices to mitigate the effects of climate change on crop production.

2.1.1. Impact of Temperature Increase

2.1.2. Impact of Elevated CO_2

Climate is an important determinant of the abundance and distribution of biological species. Over past hundred years, the global temperature has increased by 0.8 °C and is expected to reach 1.1-5.4 °C by the end of next century. On the other hand, CO_2 concentration in the atmosphere has increased drastically from 280 to 370 ppm and is likely to be doubled in 2100 (**IPCC, 2007**).

Effects of elevated temperature on insect pests. A typical effect of elevated temperature is therefore to increase consumption rates and therefore decrease the time to pupation, making them less apparent to natural enemies and in some cases increasing the potential number of generations per season.

2.1.3. Impact of Changeable Precipitation Pattern

Changeable precipitation patterns can have a significant impact on vegetable crops. Fluctuations in rainfall can lead to water stress, affecting the growth and development of the crops. Excessive rainfall can cause water logging and increase the risk of diseases, while drought conditions can result in stunted growth and reduced yields. Fluctuations in rainfall can affect the availability of water and food sources for these pests, leading to changes in their population dynamics and distribution. Additionally, variations in precipitation can influence the growth and development of plants, which in turn can affect the susceptibility of vegetables to insect infestations. . It is important for farmers to monitor weather patterns and implement appropriate irrigation strategies to mitigate the impact of unpredictable precipitation on vegetable crops.

2.2. Impact of Climate Change on Insect Pests

Climate change will have both direct as well as indirect effects on insect populations. Temperature is the major factor in global climate change that directly affects insect development, reproduction and survival. Although insect responses to global climate change will vary, the effect of global warming in general has been predicted to increase intensity of herbivore pressure on plants. Climate change will also affect insects indirectly through their host plant **Chander et al.,** . Chilli thrips, like many other insect species, may also respond to climate change by altering their distribution patterns, population sizes, and behavior. They may adapt to warmer temperatures by shifting their range to higher latitudes or elevations where conditions are more suitable. Additionally, thrips may exhibit changes in their life cycles, reproduction rates, and feeding habits in response to changing environmental conditions. However, the specific ways in which chilli thrips will respond to climate change can vary depending on the local climate, habitat, and other factors. Overall, chilli thrips may continue to be a significant pest in agricultural and horticultural settings, potentially impacting crop yields and plant health. Long-term monitoring of population levels and insect behavior, particularly in identifiably sensitive regions, may provide some of the first indications of a biological response to climate change **H C Sharma 2014.**

Direct effects of climate change on insects

Expansion of habitat range: Any increase in temperature is bound to influence the distribution of insect populations. Species might expand into regions that become favourable as a result of climate change and withdraw from regions that cease to be favourable. Climatic warming will thus allow the majority of temperate insect species to extend their ranges to higher latitudes and altitudes. Insects being the cold-blooded, temperature is the most important environmental factor influencing their behavior, distribution, development, survival, and reproduction. It is predicted that 1oC temperature increase would extend distribution of species 200 km northwards or 140 m upwards in altitude (Parry and Carter, 1989). There is a need to regularly observe activity of pests in different regions in terms of timing, population size and habitat ranges for drawing any meaningful conclusions.

Changes in over-wintering success:
With rise in temperature, onset of hibernation may be delayed, while it may be suspended earlier than usual in spring thereby increasing period of activity of pests. The pests can therefore colonize crops more quickly during spring and earlier pest flights are known to occur after milder winters. Total soluble solids and lycopene content had a strong positive relation with the pest population while it was strongly negatively correlated with the acidity. Some varieties/genotypes were also found to have lower fruit damage (Cherry tomato and MT-2) with higher yields (MT-3 and MT-2) which can be grown as an adaptation strategy to minimize the impact of fruit borer damage. This study clearly nods that with the increase in temperature, the fruit borer increases thereby increasing the risk of damage in the future. However, the adoption of suitable varieties and the development of varieties with particular biochemical characteristics may averse the impact. Further studies on agronomic management (like different dates of sowing) and bio-pesticides may be explored under different conditions for developing holistic strategies for tomato fruit borer management in the region.

How will whiteflies respond to climate change?

Whiteflies are small insects that are known to be highly adaptable to changing environmental conditions. In response to climate change, whiteflies may exhibit shifts in their distribution patterns, population sizes, and behavior. They may also evolve certain traits that help them better survive in warmer or more variable climates. However, the exact ways in which whiteflies will respond to climate change can vary depending on the specific species and the local environmental conditions. Overall, whiteflies are likely to continue to thrive and adapt to changing climates, potentially posing challenges for agriculture and ecosystems.

Climate change can have various impacts on the bitter gourd, bottle gourd, and pumpkin and cucumber fruit fly population. Warmer temperatures and changes in precipitation patterns can affect the life cycle, behavior, and distribution of these pests. It may lead to raised reproduction rates, longer breeding seasons, and expanded geographical ranges for the fruit flies. This could result in higher infestation levels in bitter gourd crops, leading to potential crop losses and economic impacts for farmers. It is essential for researchers and farmers to monitor these changes and implement appropriate pest management strategies to mitigate the effects of climate change on cucurbitaceous crop fruit fly populations. Effects of climatic factors on life history traits that include fecundity, immature development time and adult longevity of whiteflies

Change in migrating behavior: Minimum temperature plays important role in determining the global distribution of insect species rather than maximum temperature. Hence any increase in temperature will result in greater ability of insects to over-winter at higher latitudes. The global warming may affect thus migration and extend distribution of the pest further north.

Changes in interspecific interactions: The effect of climate change on species distribution and abundance could involve not only direct effect on each species individually in an ecosystem but it may also influence inter specific interactions. Rapeseed-mustard is infested by two aphid species, *Lipaphis erysimi* and *Myzus persicae*, the former being dominant during severe winters while the latter during mild winters **Chander and Phadke, 1994**. With rise in temperature, higher incidence of *Myzus persicae* may be witnessed. Such faunal shifts may also take place in other crops. Likewise, pest-natural enemy interactions are also subject to influence of climate change.

Changes in population growth rates: Warming would affect temperate annual and multivoltine species in different ways and to different degrees. In case of multivoltine species such as aphids and some lepidopterans, higher temperatures would allow faster development rate probably allowing for additional generations within a year (**Pollard and Yates, 1993**). It has been observed that tropical insects are relatively sensitive to temperature changes and are currently living very close to their optimum temperature (**Deutsch *et al*., 2008**). This implies that with 2-3oC temperature rise, ambient temperature may exceed the upper limit of favourable temperature range, thereby adversely affecting growth and development of pests. Impact of weather parameters on lepidopteron insects population and fruit damage.

2.2.1. Response of Insect Pests to Increased Temperature

Because warming temperatures influence population growth rates of insects through decreased cold-related mortality (**Bentz and Mullins 1999)** and shorter generation times **Ungerer *et al.*, 1999)** the population dynamics of onion thrips in Slovenia might change in the future. This detail could play a vital role in the case of multivoltine species, most of them are expected to wider their occurrence to higher latitudes and altitudes as was recorded e.g. in many cases of butterflies **Parmesan C *et al.*, 1999.** The effects of increased temperatures are greater for aboveground insects than for those that spend most of their life cycle in the soil, because soil is a thermally insulating medium that can buffer temperature changes and thus reduce their impact for example, under warmer conditions, aphids are less susceptible to the aphid alarm pheromone they normally release when threatened by insect predators and parasitoids, which can lead to increased predation. Whitefly populations are primarily regulated by environmental factors such as temperature, precipitation, and humidity in general. High temperature along with high humidity correlates positively with whitefly population build-up. Considering the potential impact of climate change on the ecology of insect pests, different planting dates and cropping patterns were investigated as farm-level adaption to control insect pests of cabbage and improve productivity **Tanyi *et al.*, (2018**).

Effect of treatments on cabbage pests

The ecology of insect pests is highly influenced by temperature, which may either enhance reproduction or decrease mortality of insects, leading to stronger infestations **Olesen JE, Bindi M**. Climate dynamics can lead to the emergence of new species such as the South American tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) that occurred in Europe **Jamieson MA, Trowbridge AM, Raffa KF, Lindroth RL**.

Global climate change caused by increased giving out of greenhouse gases affect the agro-ecosystems in many ways, outcome of which depend on the combined effects of environmental temperature, precipitation and other global changing factors. Insects respond to climate change by different ways i.e., changes in an insect population's physiology, biochemistry, biogeography and population dynamics. An insect population's response to a rapidly changing climate may also be erratic when insects interact with different competitors, predators and parasitoids. Due to the climate change, there is a raise in the number of insect pest population, out breaks of insect, increased number of generations and development of resistant biotypes. Climate changes cause negative impact on the natural enemies' population. This also can manipulate the overall food production system that can be at critical risk from the impacts of climate change **Yadav *et al*., 2019.** Insects are likely to be most affected by climate change because environmental factors have a strong influence on the development, reproduction, and survival of insect pests and their natural enemies **(Bale *et al*., 2002).** Global warming and climate change will trigger major changes in geographical distribution and population dynamics of insect pests, insect-host plant interactions, activity and abundance of natural enemies, and efficacy of crop protection technologies. Changes in geographical distribution and incidence will affect both crop production and food security **Sharma H.C. 2016.** The green semi looper (*Trichoplusia ni*) attacked the crop during prime vegetative growth stage and caused about 7.5-19.2% foliage damage). The impact of tomato intercropping is likely due to the confusing olfactory and visual cues from tomato plants that repelled cabbage pests.

IMPACT OF CLIMATE CHANGE ON GEOGRAPHIC DISTRIBUTION OF INSECT PESTS

Climate change will have a major effect on geographic distribution of insect pests, and low temperatures are often more important than high temperatures in determining the distribution **(Hill 1987; Thomas et al. 2001).** A common approach in predicting developmental dynamics and migration of insects in relation to weather conditions involves the use of degree-day models **(Bryant et al. 1998; Roltsch et al. 1999).**

IMPACT OF CLIMATE CHANGE ON THE BIOLOGY AND POPULATION DYNAMICS OF INSECT PEST

Overwintering of insect pests will increase as a result of climate change, producing larger spring populations as a base for a buildup in numbers in the following season. These may be vulnerable to parasitoids and predators if the latter also overwinter more readily. The diamond back moth, *Plutella xylostella* L., was able to overwinter in Alberta, Canada, in 1994 **(Dosdall 1994)**. Temperature has a strong influence on the viability and incubation period of *H. armigera* eggs, which can be predicted on the basis of degree-days required for egg hatching **(Dhillon and Sharma 2007).** Many insects such as *H. armigera*, *M. separata*, and *Spodoptera litura* (F.), which are migratory, may be well able to exploit new opportunities by moving rapidly into new areas as a result of climate change **(Sharma et al. 2002b; Sharma 2005, 2010),** Occurrence of *H. armigera* as an invasive pest in Brazil and North America has been attributed to the climate change [22,23]. *Spodoptera litura* (Fab).

Climate in this context refers to the conditions of the environment that include temperature, precipitation, humidity, air pressure, solar radiation, cloud and wind movements in a particular area over an extended period of time, usually a decade or more. Weather, on the other hand, describes these phenomena over the short term such as hours, weeks or months. Climatic and weather factors are known to influence the distribution and abundance of insects such as thrips; insects are also known to be influenced by microclimates (Davidson et al.1948a; 1948b;Tscharntke et al. 2002).

Future Research

Agricultural impact assessment based on changing yield due to increased pressure from pest due to climate change is still in its infancy. However, it is clear that human induced climate change will have impact on all feature of IPM system, pest outbreak, pollinator synchrony with flowers, efficiency of crop protection technology, parasitoid and predator efficiency **Sharma *et al*., 2014.**

In addition to the strategies we require to decide the future research on breeding climate-resilient varieties, rescheduling of crop calendars, GIS based risk mapping of crop pests and screening of pesticides with novel mode of actions. Geographic information systems (GIS), global positioning systems (GPS) and remote sensing (RS) are allied technologies that together provide a means of gathering, integrating and analyzing spatial data. How climate changes will affect development, incidence and population dynamics of insect-pest can be studied through GIS by predicting and mapping trends of probable changes in geographical distribution **Sharma *et al*., 2014.**

EFFECT OF CLIMATE CHANGE ON PEST MANAGEMENT AND FOOD SECURITY

Host plant resistance, biopesticides, natural enemies, and synthetic chemicals are some of the potential options for pest management. However, the relative efficacy of many of these pest control measures is likely to undergo change as a result of global warming. Changes in precipitation are of greater importance for agriculture than temperature changes, especially in regions where the lack of rainfall may be a limiting factor for crop production **(Parry 1990).**

Impact of climate change on insect pests, plant chemical ecology, tritrophic interactions and food production

- Change the expression of host plant resistance to insects
- Affect the efficacy of insect-resistant transgenic crops
- Affect the activity and abundance of natural enemies
- Reduce the effectiveness of bio-pesticides and synthetic pesticides for pest management

Expression of Host Plant Resistance to Insect Pests

Host plant resistance to insects is one of the most environment-friendly components of pest management. However, climate change may alter the interactions between insect pests and their host plants **(Bale et al. 2002; Sharma et al. 2005, 2010).**

Expression of Resistance to Insects in Transgenic Crop

Environmental factors, such as soil moisture, soil fertility, and temperature, have a strong influence on the expression of *Bacillus thuringiensis* (*Bt*) toxin proteins deployed in transgenic plants **(Sachs et al. 1998)**

Conclusion

Climate change is imminent and has started showing its effect on insects are no exception to it. Climate change will also impinge upon the efficacy of pest management components. It thus becomes very important to assess climate change's impact on insect pest components and adopt appropriate mitigation and adaptation measures to sustain agricultural productivity. Simulation models have been used for several applications in the area of pest management, which helped to increase the efficiency of field research greatly. These will be of even greater relevance in new emerging research areas such as climate change impacts on pests and crop yield, impacts of transgenics on the environment, pest risk analysis for sanitary and phytosanitary requirements, and pest forecasting. The changes in climatic variables especially the temperature and rainfall have a direct impact on the pest dynamics of tomato crops of the Eastern Himalayan region. In the recent past, there has been a stark increase in the temperature in the hills of the region. The variability of rainfall also increased, and the overall trend is toward a decreasing side. These changes have a profound effect on the fruit borer of tomato which is a crucial vegetable crop. The present study explored how different thermal regimes affect the pest population and its associated damage, along with the evaluation of varieties/genotypes on the basis of different biochemical, physiological, and yield characteristics. Results showed that maximum and minimum temperatures played a major role in the build-up of *H. armigera* population on tomatoes irrespective of location **Sharma *et al*., 2010.**

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In the context of India, known for its agricultural diversity, the impact of pests/diseases becomes even more pronounced. Its hill ecosystems are extremely susceptible to the consequences of climate change

Increased insect herbivore performance under elevated CO_2 is associated with lower plant defense signaling and minimal declines in nutritional quality