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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

One of the world's largest nations, India is known for its distinctive landscape, which distinguishes it as a distinct geographical entity and a global center of mega diversity. Pest populations in vegetable crops may be significantly impacted by climate change.
Additionally, warmer temperatures can lead to faster insect development and increased reproductive rates. Farmers and researchers need to monitor these changes and develop

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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.

Keywords: Temperature; rainfall; humidity; Thripstabaci; okra; red spider mite; Jassids; Earisvitella; Helicoverpa armigera; chilli; thrips onion; bitter gourd; bottle gourd; cucumber; cabbage; cauliflower.

1. INTRODUCTION

"According to Climate Change, there has been a significant increase in the atmospheric quantities of greenhouse gases such as CO2, methane, and nitrous oxide since 1750" [1]. "The majority of insects that chew show a compensatory increase in food intake. Tomatoes satisfy the needs of various populations in terms of antioxidants and nutritional nutrients. Being a significant vegetable and a C-3 crop, it is expected to be impacted by rising CO2 concentrations in the context of climate change. In India,*H. armigera*incidence is common on cotton, pigeon pea, chickpea, sunflower, tomato, sorghum; millets, okra, and corn" [2,3]. "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" [4]. Once constrained by the cycles of nature, these pests are thriving on the opportunity provided by climate change, which will have disastrous effects on crop yields and, consequently, the welfare of populations who depend on agriculture. Research elucidates the complex interrelationships among climate change, the concerning surge in pest illnesses and their consequential impacts on agriculture, underscoring their combined significance in molding the future of farming and livelihoods [1]. Whitefies, or Hemiptera: Aleyrodidae, are significant plant-damaging insects that spread hundreds of plant viruses. The life cycle and trophic relationships of plants, whiteflies, and their natural enemies are predicted to be impacted by climate change [5]. Climate change has a direct impact on the growth, reproduction, survival, population dynamics, prospective dispersion, and abundance of whitefly species in both agricultural and natural settings (Muniz and Nombela 2001) [6-8]. Insect pest infestations on tomatoes are one of the prime reasons for the low productivity of this crop Silva et al. [9]. 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" [10].

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.

2. INSECT RELATION TO CLIMATE CHANGE

"Because climatic conditions have a substantial influence on the development, reproduction, and survival of insect pests and their natural antagonists, insects are predicted to be the group most affected by climate change” [11].

Adults will emerge far earlier than previously because of the accelerated growth of immature stages brought on by global warming. Early adult emergence and an extension of the flying time are examples of observed responses. There have been reports of butterfly phenological changes across Europe [12]; (Stefanescu et al. 2003).

3. CLIMATE CHANGE AND ARTHROPOD DIVERSITY

3.1 Climate Change and Pest Status

Abiotic (temperature, humidity, rainfall, soil characteristics, pollutants, etc.) and biotic (crop-plants, weeds, insect pests, diseases, and nematodes, etc.) variables communicate with one another to determine the environment of the agro-ecosystem. Abiotic stress factors are most detrimental when they occur in combination with biotic stressors because they mitigate their effects.

3.2 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 *Plutellaxylostella* 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 *Plutellaxylostella* 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: Climate change forecasts are inherently unpredictable, particularly when it comes to multi-decadal and regional projections.

3.2.1 Impact of climate change on crop production

Crop growth and yield can be impacted by temperature variations, precipitation patterns, and extreme weather events. 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.

3.2.2 Impact of temperature increase

Impact of Elevated CO_2: An essential factor in determining the distribution and quantity of biological organisms is climate. The average global temperature has risen by 0.8 °C over the last century, and by the end of the next century, it is predicted to have increased by 1.1–5.4 °C. However, the atmospheric quantity of CO2 has significantly increased from 280 to 370 ppm and is expected to quadruple by 2100 [13].

Effects of elevated temperature on insect pests. Elevated temperatures typically have the effect of raising consumption rates, which in turn shortens the time it takes for them to pupate, making them less noticeable to their natural enemies and, in certain situations, potentially increasing the number of generations per season.

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

Source: UNEP-WCMC 2000. © World Conservation Press. Reproduced by permission of World Conservation Press. Permission to reuse must be obtained from the rightsholder

2.1.3 Effects of varying precipitation patterns

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.

3.3 Climate Change's Effect on Insect Pests

Insect populations are going to be impacted by climate change in both direct and indirect ways. The primary driver of global climate change that has an immediate impact on the growth, reproduction, and survival of insects is temperature. The impact of global warming is expected to intensify herbivore pressure on plants, even if insect reactions to climate change will differ. Insects will be indirectly impacted by climate change through their host plant. Chander et al.,.Chillithrips, 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. Some of the earliest signs of a biological reaction to climate change may come from long-term observation of population sizes and insect behaviour, especially in clearly susceptible areas. H C Sharma 2014.

3.4 Insects Directly Impacted by Climate Change

Expansion of habitat range: It is inevitable that any rise in temperature will have an impact on insect population distribution. As a result of climate change, species may spread into more favourable locations and retreat from less favourable ones. Thus, most temperate insect species will be able to expand their ranges to higher latitudes and elevations due to climate warming. Since insects are cold-blooded creatures, temperature has the greatest influence on their distribution, behaviour, growth, survival, and ability to reproduce. A 1oC temperature increase is anticipated to move a species' distribution 200 km northward or 140 m higher [14]. In order to make any kind of inference, it is necessary to constantly monitor the behaviour of pests in various areas with respect to timing, population size, and habitat ranges.

3.5 Changes in Over-Wintering Success

Temperature increases may cause hibernation to begin later than usual or to conclude sooner than usual in the spring, lengthening the time of pest activity. Because of this, pests can colonise crops in the springtime more quickly, and early pest flights are known to happen following milder winters. The pest population had a substantial positive correlation with total soluble solids and lycopene content, whereas there was a large negative correlation with acidity. A approach for adapting to reduce the impact of fruit borer damage is to cultivate certain varieties/genotypes, such as MT-2 and Cherry tomato, which have higher yields and less fruit damage. This study unequivocally indicates that as temperatures rise, so do fruit borer populations, which in turn raised.

How will whiteflies respond toclimate 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 behaviour: Rather than maximum temperature, minimum temperature has a significant impact on the worldwide distribution of insect species. Therefore, insects will be better able to overwinter at higher latitudes with any increase in temperature. Global warming may have an impact on this movement and cause the pest's range to spread further north.

Changes in inter specific interactions: Inter specific interactions may vary as a result of climate change, which may have an impact on inter specific interactions in addition to directly affecting each species' individual status within an ecosystem. Two aphid species, *Lipaphis erysimi* and *Myzus persicae*, infest rapeseed-mustard; the former predominates during harsh winters and the latter during mild ones.

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” [15]. “It has been observed that tropical insects are relatively sensitive to temperature changes and are currently living very close to their optimum temperature” [16]. 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.

3.6 Response of Insect Pests to Increased Temperature

Because warming temperatures influence population growth rates of insects through decreased cold-related mortality [17] 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” [18]. “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. The main environmental variables that control whitefly populations are temperature, general humidity, and precipitation. High temperature along with high humidity correlates positively with whitefly population buildup. In order to reduce insect pests of cabbage and increase productivity at the farm level, several planting dates and cropping patterns were examined in light of the possible effects of climate change on the ecology of insect pests” Tanyi et al. [19].

3.7 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 *Tutaabsoluta* (Meyrick) (Lepidoptera: Gelechiidae) that occurred in Europe” Jamieson MA, Trowbridge AM, Raffa KF, Lindroth RL.

In vegetables crop ecosystems are impacted by global climate change, which is brought about by increased greenhouse gas emissions. The consequences of these changes on the environment, temperature, precipitation, and other variables are interdependent. Insect populations adapt to climate change in a variety of ways, including through modifications to their physiology, biochemistry, biogeography, and population dynamics. Interactions between insects and various rivals, predators, and parasitoids can also cause an insect population's reaction to a rapidly changing climate to be unpredictable. The number of insect pests, bug outbreaks, number of generations, and development of resistant biotypes are all on the rise as a result of climate change. Changes in climate have an adverse effect on the number of natural enemies. Additionally, this can alter the entire food production system that Yadav et al., 2019. Because climatic conditions have a substantial influence on the development, reproduction, and survival of insect pests and their natural antagonists, insects are anticipated to be the group most affected by climate change [11]. Significant changes in the geographic distribution and population dynamics of insect pests, interactions between insect pests and host plants, the activity and abundance of natural enemies, and the effectiveness of crop protection technology will be brought about by climate change and global warming. Changes in the occurrence and distribution of crops geographically will have an impact on food security and crop productivity Sharma H.C. 2016.The green semilooper (*Trichoplusiani*) attacked the crop during prime vegetative growth stage and caused about 7.5-19.2% foliage damage).The impact of intercropping tomatoes is probably because the plants' perplexing scent and visual cues deterred cabbage pests. Plant crops like millet, jowar and maize in two to three rows as barrier crops in the border of the main field for protection against pests like fruit borers and white flies.

4. THE EFFECT OF CLIMATE CHANGE ON AN INSECT PESTS' GEOGRAPHIC SPREAD

The geographic spread of insect pests will be significantly impacted by climate change, and low temperatures are frequently more significant than high temperatures in defining the dispersion [20,21]. Using degree-day models is a typical method for forecasting the dynamics of insect migration and development in response to weather [22].

5. AFFECT OF CLIMATE CHANGE ON THE POPULATION DYNAMICS AND BIOLOGY OF INSECT PEST

Climate change will lead to an increase in insect pest overwintering, resulting in greater spring populations that will serve as a foundation for a building in numbers the following season. In the event that predators also overwinter more easily, these could be at risk from parasitoids and other threats. *Plutella xylostella* L., the diamond back moth, was able to survive the winter in Alberta, Canada, in 1994 [23]. The degree-days essential to egg hatching can be used to forecast the viability and incubation period of *H. armigera* eggs, which are highly influenced by temperature [24]. Due to climate change, a number of migratory insects, including *H. armigera*, *M. separata*, and *Spodoptera litura* (F.), may be well suited to take advantage of new chances by quickly expanding into new locations [25-27], Climate change has been linked to the invasive pest H. armigera's occurrence in Brazil and North America [25,26]. *Spodoptera litura* (Fab).

In this application, "climate" refers to the environmental factors that affect a specific location over an extended period of time, typically a decade or more, and include temperature, precipitation, humidity, air pressure, sun radiation, clouds, and wind movements. In contrast, weather refers to these occurrences that occur over short time periods, such hours, weeks, or months. It is well recognized that microclimates have an impact on insects, and that weather and climatic variables impact the distribution and population of some insects, including thrips [28-30].

5.1 Future Research

We are still in the early stages of agricultural impact assessment based on altered yield as a result of increasing pest misery bringing on by climate change. But it is certain that all aspects of the integrated insect Management (IPM) system including insect outbreaks, pollinator synchrony with flowering plants, crop protection technology performance and parasitoid and predator efficiency-will be impacted by human-caused climate change [26].

In addition to the tactics used to determine the direction of future research on cultivating climate-resilient varieties, crop season rescheduling, and GIS-based risk mapping of agricultural pests and pesticide screening with innovative modes of action. Global positioning systems (GPS), geographic information systems (GIS), and remote sensing (RS) are related technologies that work together to collect, manage, and evaluate spatial data. Using GIS, it is possible to study how changes in climate may impact the growth, occurrence, and population dynamics of insect pests by forecasting and charting potential shifts in their geographic range. Sharma et al., 2014.

6. IMPACT OF CLIMATE CHANGE ON FOOD SECURITY AND PEST MANAGEMENT

Among the possible strategies for managing pests are synthetic insecticides, natural enemies, biopesticides, and host plant resistance. However, as a result of global warming, it is expected that the relative effectiveness of many of these pest management strategies may alter. Precipitation variations are more significant for agriculture than temperature variations, particularly in areas where agricultural productivity may be constrained by a lack of rainfall [31].

- ➢ Effects of climate change on food production, tritrophic relationships, plant chemical ecology, and insect pests
- ➢ Modify the expression of insect resistance in host plants; impact the effectiveness of transgenic crops resistant to insects; and influence the quantity and activity of natural enemies.
- ➢ Decrease the efficiency of synthetic and biopesticides in controlling pests.

6.1 Host Plant Resistance to Insect Pests Expression

One of the pest management strategies *i.e*. least noxious to the environment is host plant resistance to insects. Climate change, however, might modify how insect pests and their host plants interact [11,26].

6.2 Transgenic Brinjal Crop Expression of Insect Resistance

The expression of *Bacillus thuringiensis* (Bt) toxin proteins in transgenic plants is strongly influenced by environmental conditions, including temperature, soil fertility, and moisture content [32-40].

7. CONCLUSION

The effects of climate change are already being felt by insects, and they are not an exception. There will be an impact of climate change on the effectiveness of pest management strategies. In order to maintain vegetables productivity, it is crucial to evaluate how climate change is affecting the components of insect pests and to implement suitable mitigation and adaptation strategies. Numerous applications of simulation models in the field of pest management have significantly improved the effectiveness of field research. These will be even more important in newly developing study fields including pest forecasting, transgenics' effects on the environment, pest risk analysis for sanitary and phytosanitary regulations, and the effects of climate change on pests and crop productivity. The variations in the climate, particularly the temperature. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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