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11. Impact of Climate Change on Agriculture Insect- Pest

Kumari Ruchika, Poonam Kumari, Sunil Kumar

Department of Animal Sciences,
School of Life Sciences, Central University of Himachal Pradesh,
Kangra.

Abstract:

Climate change is having an important impact on agricultural systems worldwide, influencing not only crop productivity but also the populations and behaviors of insect pests. In recent years, changes in temperature and precipitation patterns have led to shifts in the distribution and abundance of insect pests, posing challenges for farmers and threatening food security. Climate changes can impact insect pests in multiple ways.

They may result in several negative outcomes, including increased risk of invasion through migratory pests, increased incidence of insect-transmitted plant diseases, more generations, increased survival during overwintering, altered plant-pest synchrony, and decreased effectiveness of biological control, especially natural enemies. Consequently, there is a significant chance of crop economic losses and a threat to the food security of humans. It is a significant factor in the dynamics of pest populations, necessitating the development of adaptive management techniques to address the evolving condition of pests. It is possible to determine a number of study goals for the future on how agricultural insect pests are affected by climate change. This chapter review that how climate change is influencing the dynamics of agricultural insect and discusses potential adaptation strategies for mitigating this impact.

Keywords:

Climate change, Agricultural systems, Insect pests, Crop productivity, Adaptation strategies.

11.1 Introduction:

Climate change is a worldwide spectacle that is transforming the environment in which agricultural systems operate. Increasing temperatures, shifting precipitation patterns, and acute weather events are all influencing the dynamics of insect pest populations.

These changes are straining existing pest management strategies as pests become harder and more pervasive. Integrated pest management solutions that integrate sustainable and environmentally friendly practices are becoming increasingly crucial in today's shifting world. Climate change has the ability to shift the location and quantity of insect pests in agricultural systems. Warmer temperatures can hasten the development and reproduction of specific insect species, resulting in greater pest burden on crops.

Furthermore, variations in precipitation patterns might generate conditions that promote insect survival and dissemination. Collaboration among academics, farmers, and policymakers is critical for discovering effective solutions to combat the effects of climate change on agriculture and assure food security for future generations.

To limit the effects of climate change on agricultural insects, farmers and researchers are testing a variety of adaptation measures. These include developing pest-resistant crop types, employing integrated pest management approaches, and implementing climate-smart agriculture techniques. By combining these measures with good monitoring and early warning systems, farmers can better prepare for and respond to the changing dynamics of insect pest populations.

11.2 Climate Change Effects on Agricultural Insect Pests:

11.2.1 Elevated Temperature:

Climate change and weather anomalies affect insect pests, an important biotic component that affects crops both directly and indirectly (Aggarwal & Singh, 2012). Additionally, it has an immediate effect on insects' growth, their survival, development, and spread. Because they are poikilothermic, temperature fluctuations have a big effect on insects (Kocmánková et al., 2009). Insect behavior, dispersion, development, and reproduction are all influenced by temperature. Insect physiology is significantly impacted by temperature variations; for every 10 degrees Celsius increase, their metabolic rate doubles (Dukes et al., 2009).

Warmer temperatures stimulate insect eating, activity, and dispersal, which may change population dynamics. Temperature affects mobility, metabolism, metamorphosis, and host availability, which all have an impact on pest population and dynamics (Bale et al., 2002).

Increased insect populations could lead to earlier infestations and crop damage as a result of global warming. Under global warming scenarios, many insect pests' ideal temperatures could result in a rise in pest infestations. However, because insects have different demands, tolerances, and impacts of temperature, there is no guarantee that crop losses and pest numbers would increase uniformly (Cannon, 1998). Furthermore, outbreaks of bark and wood-boring insects are impacted by temperature changes in terms of frequency, severity, and area. For example, the western pine beetle's development rate has increased and its overwinter death rate has dropped due to recent warming, which has resulted in higher population expansion during droughts.

According to research, longer insect life cycles and earlier emergence could result from increased temperatures. For instance, Evans et al. demonstrated that rising temperatures weaken the biocontrol attempt for cereal leaf beetles by creating a phenological mismatch between the insects' natural predator and prey (Pollard & Yates, 1993). Additionally, multivoltine insects like aphids and the great cabbage white butterfly can develop more quickly at higher temperatures, leading to an increase in the number of yearly generations. Climate change-related alterations in the host ranges of insect pests are becoming more frequent and they can have a significant effect on agricultural productivity.

An illustration of how global warming impacts insects is the expansion of pests' ranges and increases in their ability to survive the winter in species like the cotton bollworm and maize earworm, which pose serious problems for crop output and pest management in maize, a key agricultural crop in the world (Diffenbaugh et al., 2008). Due to their potential to result in large financial losses from crop production and pest management efforts, these pests pose a threat to the agricultural sector. Agronomic and scientific research must keep examining and addressing the effects of climate change on insects and their effects on crops in light of the anticipated rise in temperatures. It is often well-known that aphids are penetrating to temperature fluctuations (Wang et al., 2015).

Due to their small bodies and quick life cycles, these insects are susceptible to major changes in their movement patterns brought on by rising temperatures. This can result in unexpected outbreaks and large financial losses in the forestry and agricultural industries. The increase in the overwinter survival rate of pests like cotton bollworm and maize earworm due to global warming has resulted in an expansion of their geographical range and considerable challenges for agricultural output and pest management.

11.2.2 Increased Carbon Dioxide Level:

Photosynthesis depends on CO_2, and high concentrations of this gas might affect plant physiology. ECC results in higher rates of photosynthesis, more stomatal openings, and a reduction in water loss through transpiration. The amount of carbohydrates in leaves rises with rising CO_2 levels, but nitrogen levels fall. Plant defense mechanisms against insects can be impacted by ECC, as it has the ability to change nutritional levels, especially those of protein (Stiling & Cornelissen, 2007). ECC increases salicylic acid (SA) and decreases the buildup of the defense hormone jasmonic acid (JA) in plants. For example, by inhibiting JA accumulation, ECC has been demonstrated to reduce tomato resistance to the cotton bollworm (*Helicoverpa armigera Hübner* (Lepidoptera: Noctuidae)).

ECC can affect insect pest population size, growth, fertility, and rate of food consumptio. For instance, ECC enhanced the eating and reproduction of the western corn rootworm (*Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae)) and the Japanese beetle (*Popillia japonica Newman* (Scarabaeidae: Coleoptera)) (Sánchez-Guillén et al., 2016). Molecular resistance investigations in lepidopteran insects have shown that ECC levels can affect a plant's susceptibility to insect pests; in melons, resistance was shown to be lower than in tobacco. Research has indicated that in interactions between chickpea and *H. armigera,* both the insect survival rate and the harm produced by *H. armigera* are reduced at ECC levels (Sharma et al., 2016). Plants with higher ECC levels have a smaller pool of carbohydrates and are therefore less attractive or even poisonous to insect larvae because photo assimilates are reallocated to defense metabolites. Insects that consume plants may be affected by ECC in terms of quantity, kind, and presence. For instance, ECC raises the quantity of aphids but has no effect on the rate of parasitism.

Due to lower nitrogen concentrations, ECC also lowers the nutritional quality of plants, which increases the amount of food consumed by insects. Moreover, since ECC has been shown to increase aphid metabolic rate and feeding behavior, ECC levels may have an impact on pest behavior.

11.2.3 Changing Precipitation:

Variations in precipitation can affect soil water availability, atmospheric water vapor fluxes, stream flow, evapotranspiration, and precipitation regimes. These changes can also affect the quantitative, qualitative, and temporal characteristics of the precipitation events. Many insect pests are susceptible to variations in precipitation, which affects their survival and ability to reproduce, ultimately affecting population fluctuations. Changes in precipitation patterns can also have an effect on wireworm populations, which can seriously harm crops (Johnson et al., 2008).

On the other hand, a lot of rain might be advantageous since it can remove little pests like jassids, aphids, mites, and whiteflies. Variations in precipitation can also affect the nutritional value of plants that herbivores eat, which can affect how well they perform. The detrimental effects of prolonged drought on the activity and population of this pest's natural predators, *Mythimna separata* (Walker) (Lepidoptera: Noctuidae) populations may increase in response to heavy rains (Emwas et al., 2019). Furthermore, studies have demonstrated that plants under water stress may experience a reduction in their biological functions, which increases their susceptibility to pests and illnesses.

11.2.4 Insect Pest Distribution:

Climate change significantly impacts insect pests, with severe temperature shifts projected. Indirect impacts include host effects, competition, and pressure from natural enemies. Direct influences affect insects' life-table parameters, while precipitation levels affect their biology and distribution, affecting crop productivity worldwide (Frank, 2021). Climate change is expected to significantly impact crop-harming pest movements, with temperature and precipitation being key factors. Changes in rainfall patterns have been linked to desert locust outbreaks in East Africa. Water restrictions may reduce outbreak frequency, but increased extreme weather events may cause new ones (Thomson et al., 2010; Zeng et al., 2020). Insect pests' effects vary, with some areas experiencing a decrease in generations and others experiencing an increase.

Tuta absoluta (Lepidoptera: Gelechiidae), the South American tomato pinworm, is predicted to have negative effects close to the equator but beneficial effects close to the poles. It is anticipated that the maize leafhopper, *Dalbulus maidis* (Homoptera: Cicadellidae), a major vector of maize crop diseases, will face a decline in suitable habitat in its native range, but that its range expansion into continental African countries could represent a serious threat (Robinet & Roques, 2010). Climate change is ultimately predicted to worsen the effects of pest populations' geographic ranges, resulting in decreased crop productivity and food security.

11.2.5 Overwintering Survival:

Insects, being poikilothermic species, are sensitive to seasonal climate changes, particularly temperature. They face difficulties in cold climates, affecting their physiological processes and leading to mortality. They have developed overwintering tactics like diapause and freeze avoidance to survive low temperatures.

Diapause is essential for insects' life cycle and survival. However, as a result of temperature and precipitation variations brought on by climate change, photoperiod is being altered. This distorts the timing of diapause and increases the likelihood of extremely low temperatures if insects enter diapause later in their life cycle (Kerr et al., 2020). For example, adult green stinkbugs in northern Japan can survive the winter if they undergo diapause during the preceding season (Bradley Richards, 2020). However, they perish during the winter when they reach their nymphal stage. On the other hand, insects can mature before winter in the southern regions due to longer growing seasons.

11.2.6 Pest Generation Number:

Temperature is a crucial climatic factor affecting insect phenology, and global warming is expected to increase insect pest populations, potentially endangering food supply. Growing degree days (GDD) measure an organism's ability to withstand heat development. Rising temperatures will cause multivoltine cabbage white butterflies (*Pieris brassicae L*.) to mature faster and produce more generations annually (Mayr et al., 2020). Insects with annual life cycles will grow and develop more quickly than those with longer life cycles. Long-term monitoring programs suggest that climate change may impact when insect pests appear, leading to changes in the emergence schedule and higher populations in subsequent generations, potentially destabilizing agriculture and impacting crop yields and the world's food supply.

11.2.7 Invasive Alien Insect Species:

Invasive alien species (IAS) are organisms intentionally or unintentionally introduced into environments outside their natural range, such as nuisance and disease-carrying insects. Due to increased travel, trade, and agriculture, many IAS have spread rapidly, posing a significant threat to global biodiversity and causing financial losses for natural ecosystems. While a limited percentage of introduced species successfully establish themselves, climate change may expand their range, become more densely populated, and take longer to mature, potentially affecting agricultural productivity (Pérez et al., 2022).

Climate change can also impact species dispersal, growth, and survival in new habitats, potentially allowing them to colonize inappropriate areas. Rising temperatures, due to inherent thermal constraints, will significantly affect ecosystems and organisms. Both native and exotic insect pests' responses to global warming are unknown, and it is uncertain whether increased temperatures will be beneficial for their growth and survival (Reid et al., 2021).

Insect invasion involves the travel, introduction, settlement, and spread of invasive insect species. Climate change can directly impact the introduction and movement of these insects, with extreme weather events transferring pests to new areas. Propagule pressure, or the introduction of an individual species, affects establishment success (Ward & Masters, 2007). Invasive insects' ranges are expanding slowly due to climate change, with their wide tolerance range allowing them to spread to new habitats. The spread of invasive species is fueled by plasticity, which allows them to adapt to unfamiliar environments through physiological, developmental, behavioral, or phenotypic features.

11.2.8 Effectiveness of Natural Enemies as Biological Control:

Climate change is expected to significantly impact the success of biocontrol initiatives, particularly in controlling plant-eating insects and their natural enemies. These interactions are crucial for the environment, particularly in forestry and agriculture. Climate change can disrupt the tri-trophic interaction among host plants, insects, and natural enemies, potentially affecting the effectiveness of biocontrol. Some natural enemies, such as parasitic wasps and ladybirds, control pest insect populations, but regular temperature rises could cause natural enemies to develop faster than prey, potentially leading to their extinction (Morimoto et al., 2019). Climate change disrupts the cereal leaf beetle's biocontrol, affecting not only its predator but also crop distribution, forcing herbivores to move to areas where they might be attacked. This spatial resynchronization can lead to herbivores establishing large populations in unexplored areas. Generalist food webs may be more resilient to climate change effects (Kiritani, 2013). Elevated temperatures, precipitation patterns, and rising CO_2 levels affect plant productivity, herbivore populations, and predator-prey interactions. High CO_2 environments provide various nutrient sources for herbivores.

Aphid populations increased with elevated temperature and CO_2, but parasitism increased with temperature but not necessarily with CO_2. Life history features determine how high CO_2 affects species. A parasitic wasp went extinct due to temperature increases and ECC (Notaro et al., 2009). Predator efficiency is unclear, but Asian ladybirds preferred aphids in higher CO_2 environments. Climate change can directly affect predators and plants, so it's crucial to consider all trophic levels when evaluating its effects.

11.3 Strategies for Pest Management in A Changing Climate: Adaptation and Mitigation:

Using risk management techniques and lowering possible hazards from climate change consequences are two aspects of climate change adaptation. Although the precise nature of the interactions between insects and plants in ecosystems is still unknown, it is anticipated to increase the geographic range and predictability of pest outbreaks. Agriculture production systems' ability to adapt is influenced by biological, economic, and social variables. Modified integrated pest management techniques, monitoring of insect pest populations and the climate, and modelling prediction tools are some of the strategies to stop the spread of pests and lessen their harmful effects.

11.3.1 Adapted Integrated Pest Control Techniques:

IPM (Integrated Pest Management) is crucial in sustainable agriculture to control harmful species like insects and mites. Decisions on control measures are based on modern tools and scientifically validated thresholds (Gomez-Zavaglia et al., 2020). The FAO recommends a dual strategy involving global and regional action, early detection systems, and new agricultural practices. Drought stress affects crop protection, necessitating modified cropping practices and adaptive management strategies (Barzman et al., 2015). Understanding global warming's effects on synthetic insecticide performance is essential for developing sustainable pest control agents.

11.3.2 Measuring Distribution and Abundance:

Access to long-term data is crucial for assessing changes in insect pest species population dynamics under changing climate regimes. Biological reactions can be inferred from monitoring pest populations and behavior, especially in areas vulnerable to climate change. Invasive plants and animals must be effectively managed and monitored to avoid generating commercial problems in new areas (Heeb et al., 2019). The protection of biodiversity and control of pests call for flexible solutions. An international management strategy is required for efficient risk assessment and monitoring (Kumar et al., 2014). Improved cooperation between countries and regions is essential.

11.3.3 Forecasting Climate and Developing Models:

Climate change adaptation strategies are challenging due to the heterogeneity of global temperature and climate parameters. Integrated strategies must consider all aspects of agricultural production and pest management strategies must tolerate regional climate change. Sensitivity analyses and combined results from projected climate change scenarios can help inform pest management personnel in designing adaptation measures (Stiling & Cornelissen, 2007). Climate models combined with environmental requirements of pest species can project possible global changes, increasing the ability to predict insect infestation outcomes. Correlative models, such as MaxEnt, Bioclim, and Random Forest, are commonly used for predicting climate change impacts on biodiversity and assessing extinction rates (Kumar et al., 2014). Mechanistic models, on the other hand, use environmental variables and species tolerances to predict future species distributions. They exclude regions that constrain physiological performance and extrapolate beyond known conditions (Yonow et al., 2018).

11.4 Conclusion:

Food security is seriously threatened by agricultural insect pests, especially in light of climate change. It is necessary to put in place efficient management techniques to deal with this problem. Climate change will affect the distribution and behavior of pests; hence it is imperative to understand their biology and behavior in the environment. For prompt response, it is crucial to track changes in pest populations using conventional techniques, remote sensing technology, and citizen science projects. IPM strategies should be used to minimize the use of pesticides and lessen their negative effects on the environment. These strategies combine chemical, biological, and cultural methods. Early warning systems and pest outbreak control can be facilitated by forecasting systems that rely on historical records, remote sensing data, and citizen science reports. Creating crop types resistant to pests and drought can increase food security and decrease dependency.

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