Impact of Climate Change on Insect Diversity

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ABSTRACT

Climate change has emerged as one of the most significant drivers of biodiversity loss, with profound effects on insect diversity across different ecosystems. This has resulted into disruption of not only ecosystem components from biotic to abiotic through human-induced environmental alterations but also threatened food security, contributed to weather pattern disruptions across the globe. Agricultural crops and their corresponding pests are directly and indirectly affected by climate change through altered temperature, rainfall, relative humidity and CO2 levels. Insects are highly sensitive to environmental changes and rising temperatures influence their physiology and metabolism, leading to shifts in distribution, phenology, life cycles and interspecific interactions. Recent monitoring shows annual declines of 6.6% in abundance, thus the changes made due to climate change interfere with overall ecological processes, creating imbalance in ecosystem functioning crucial for sustainable agriculture.

INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." These changes pose significant challenges to the biodiversity and sustainability of life on Earth. Insects are organisms with short generation times and high reproductive potential, are particularly sensitive to climatic variations and are expected to respond rapidly to changing environmental conditions (Weiskopf *et al*., 2020). They play a vital role in ecosystem functioning through complex biotic interactions, serving as pollinators, decomposers and natural enemies. However, evidence shows major decline in insect populations. This decline threatens key ecosystem functions such as nutrient cycling, soil formation, organic matter decomposition, water purification, biological pest regulation, pollination and food web dynamics (Van der Sluijs, 2020). Climate change creates new ecological niches that provides opportunities for insect pests to establish and spread in new geographical areas. In addition, extreme climatic events are going to increase in frequency, intensity and duration due to alarming climate variability.

1. Major Climatic Factors Influencing Insect Dynamics

1.1 Effects of Increased Temperature on Insect Pest behaviour and biology

Insect physiology is highly sensitive to temperature. Elevated temperatures accelerate feeding, development, reproduction, influencing survival, population growth, and distribution. Aboveground insects are more affected than soil-dwelling species due to limited thermal buffering. With global temperatures projected to rise by 1.8–4 °C, conditions are expected to favour many insect pests, leading to increased infestation risks and impacts on agricultural systems. For example: bumble bee diversity declines as the number of days with excessive heat increases (Walters *et al*., 2022).

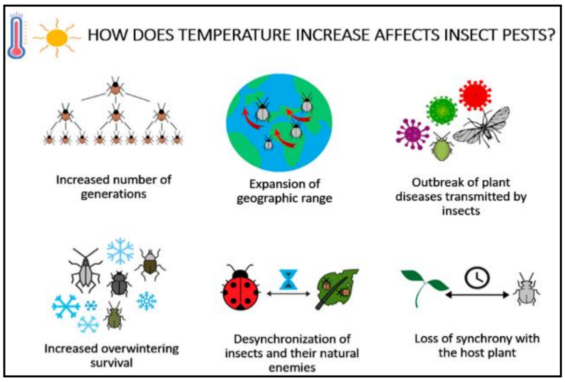

FIGURE 1: Showing effect of Increased Temperature on Insect Pests Populations. Source: MDPI

1.2 Effects of Altered Precipitation on Insect Pest behaviour and biology

Climate change is altering precipitation patterns, causing affect in insect life cycles. Aquatic insects such as mosquitoes rely on water for breeding; reduced rainfall can limit their populations whereas increased precipitation may promote outbreaks by expanding breeding sites. Example: Soil-dwelling insects like ants and termites are also affected as drought reduces their activity and impacts nutrient cycling, while excessive rainfall can destroy habitats, disrupt reproduction and increase mortality.

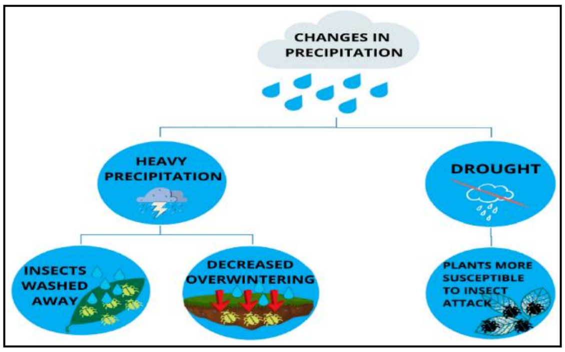

FIGURE 2: Showing effect of Altered Precipitations on Insect Pests Populations. Source: MDPI

1.3 Effects of Increased CO_2 Concentration on Insect Pest behaviour and biology

Rising atmospheric CO_2 alters herbivorous insect distribution, abundance and performance by changing host plant quality in C3 crops like wheat and rice more than C4 crops like corn. Increased CO_2 boosts plant photosynthesis and growth but lowers leaf nitrogen via higher C:N ratios, leading to overfeeding by foliage chewers such as caterpillars up to 17% increased consumption and greater crop damage. Example: Soybeans showed 57% more insect damage under high CO_2 due to elevated sugars stimulating pests like Japanese beetles.

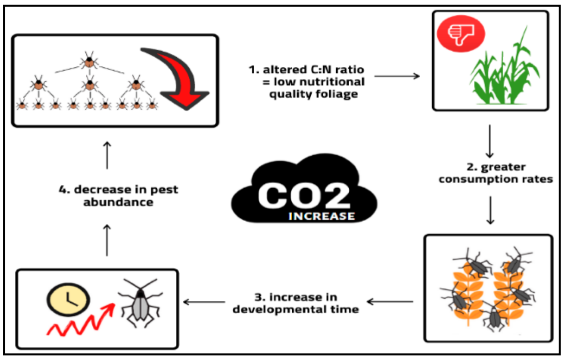

FIGURE 3: Showing effect of Increased CO_2 Concentration on Insect Pests. Source: MDPI

2. Impact on Insect Pest Diversity

2.1 Changes in Species Composition and Diversity

Climate change significantly alters insect pest diversity by modifying species composition within ecosystems. Rising temperatures and changing environmental conditions favour adaptable pest species, leading to increased dominance of certain insects while more sensitive species decline. Thus, resulting in overall loss of biodiversity. Additionally, invasive pest species are more likely to establish and spread under changing climatic conditions, further altering native insect communities (Bebber *et al*., 2013).

2.2 Alteration in Pest Population Structure and Outbreak Patterns

Climate change influences not only the diversity but also the structure and outbreak patterns of insect pest populations. Changes in precipitation and humidity further affect population dynamics by influencing breeding success and mortality rates. As a result, pest populations become more unpredictable. These shifts pose challenges for agricultural systems, as they can increase crop damage and complicate pest control measures (Skendžić *et al*., 2021).

3. Effects on beneficial Insect Diversity

3.1. Decline in Pollinator Abundance and Efficiency

Climate change has significantly affected the abundance and activity of pollinators such as bees, butterflies and other beneficial insects. Rising temperatures and altered precipitation has led to temporal mismatches between pollinators and plants. These mismatches reduce food availability, ultimately reducing pollinator survival and reproductive success. Decline in pollinator abundance threatens crop productivity and ecosystem stability as many agricultural crops depend heavily on insect mediated pollination.

3.2 Impact on Natural Enemies and Biological Control

Beneficial insects such as predators and parasitoids play a crucial role in regulating pest populations. Also, extreme climatic events can cause higher mortality in these species compared to pests, leading to an imbalance in predator-prey interactions. This reduction in natural enemy populations results in increased pest outbreaks i.e. Resurgence and more reliance on chemical control methods.

4. Adaptation and Mitigation Strategies

Conservation of insect diversity under climate change requires integrated strategies, viz. habitat restoration, sustainable agricultural practices and long-term monitoring. Enhancing landscape diversity and promoting ecological resilience are critical for mitigating climate induced impacts on insect populations.

CONCLUSION

Climate change is reshaping insect diversity and pest dynamics by altering key environmental factors such as temperature and rainfall. These changes influence insect biology, distribution, and interactions, ultimately affecting ecosystem stability and agricultural productivity. Since insect pests are closely linked to climatic conditions, their impact on crop yields is likely to increase under changing climates. Therefore, a clear understanding of these relationships is crucial for effective pest management and sustainable food production.

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