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CLIMATE CHANGE, INSECTS, AND FOOD PRODUCTION: CHALLENGES AND OPPORTUNITIES

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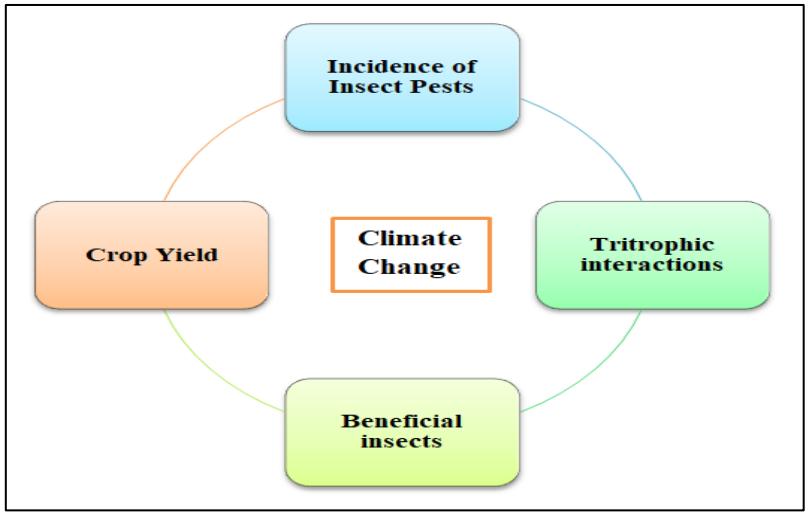
Climate change exerts a profound impact on global food production systems, posing significant challenges to food security and agricultural sustainability. Insects emerge as pivotal actors within agricultural ecosystems, serving both as pests and beneficial organisms. As the climate undergoes further shifts, the intricate interplay between insects and food production intensifies, creating complexities. This article delves into the ramifications of climate change on the roles of insects in agriculture, highlighting the hurdles it imposes on food production. By examining these dynamics, we can better understand the evolving landscape of agriculture amidst the pressures of a changing climate.

The burgeoning global population necessitates a doubling of agricultural production by 2050 to meet escalating demands. Modern agricultural research focuses on mitigating climate change impacts like rising temperatures, increased atmospheric carbon dioxide, extreme weather events, and shifting precipitation patterns (Tilman *et al.*, 2011). Changes in precipitation patterns, particularly in dry regions, hold significance for crop production. Additionally, pests, affected by climate fluctuations, pose a significant threat to agriculture. Addressing these challenges entails implementing integrated pest management (IPM) strategies, emphasizing eco-friendly practices and predictive modelling techniques.



Climate Change and The Incidence of Insect Pests

Climate change can increase the populations of *Helicoverpa armigera* and *Maruca vitrata*, leading them to migrate to temperate regions, which could significantly impact legumes and related crops. *Spodoptera litura* has become a major pest under elevated CO2 levels. Additionally, the woolly aphid, *Ceratovacuna lanigera*, has emerged as a significant threat in Maharashtra due to climate change, spreading from its initial sighting in West Bengal in 1958 to Central and South India. Pigeonpea planted in August experiences higher incidences of *H. armigera* and *Spodoptera exigua* compared to September plantings. Furthermore, plant stress induced by climate change may exacerbate pest outbreaks by compromising the plant's defense mechanisms through altered physiological processes (War *et al.*, 2014).

Chemical Ecology and Tritrophic Interactions

The rise in global temperature, atmospheric CO2 levels, and the duration of dry seasons is likely to impact plant-herbivore interactions in tropical regions, bearing significant consequences for food security and natural ecosystems. Elevated CO2 levels may diminish nitrogen-based defenses like alkaloids while bolstering carbon-based defenses such as tannins. Additionally, under heightened CO2 levels, soybean plants show impaired jasmonic acid-mediated signaling of defensive pathways, reducing the production of defensive proteins (CystPIs) and making plants more susceptible to insect pests. Furthermore, this environmental shift can disrupt the symbiotic relationship between insect pests and fungi, affecting hosts and symbionts differently (Zavala *et al.*, 2008).

Impact on Beneficial Insects

Changes in interspecific interactions may impact the efficiency of natural enemies. Increased CO2 levels reduced the population of aphid parasitoid *Diaeretiella rapae* by approximately 50% and led to shorter adult lifespans. Additionally, *Cotesia melanoscela* experienced heightened larval and pupal mortality and reduced performance under elevated CO2 conditions. However, certain natural enemies could become more effective in altered climates. For instance, reduced nitrogen levels resulted in decreased growth of *H. armigera* larvae, making them susceptible to predation by *Oechalia schellenbergii*. Similarly, *Leis axyridis* showed increased prey consumption of *Aphis gossypii* under elevated CO2 conditions (Boullis *et al.*, 2014).

Climate Change and Crop Yield

Rising temperatures linked to climate change pose significant threats to food security, particularly in developing nations within semi-arid tropics. Each degree increase above 32°C has been found to reduce wheat and rice yields by 5 %. Maize, wheat, and rice are anticipated to suffer most from climate change, particularly in dry/rainfed areas. Changes in temperature, CO2 levels, and precipitation affect photosynthesis, respiration, and grain filling, leading to altered plant development and reduced yields. These shifts also impact cropping systems, altering growing seasons, planting, and harvesting dates, necessitating changes in crop varieties. Additionally, rising sea levels and desertification will further diminish available cropping areas (Kang *et al.*, 2009).

Edible Insects as Alternative Food Sources

As the impacts of climate change on traditional food production become more apparent, there is growing interest in exploring alternative food sources. Insects are great resources of vitamins and micronutrients. For example, caterpillars are especially rich in B1, B2 and B6, bee brood is rich in vitamins A and D etc. Insects are highly efficient in converting feed into edible biomass, requiring less land, water, and resources compared to conventional livestock. In many cultures worldwide, consuming insects is already a common practice. The use of edible insects in food production and processing can diversify diets, promote food security, and contribute to sustainable agriculture (Tang *et al.*, 2019).

Opportunities for Sustainable Pest Management

Addressing climate change, insect threats, and food production demands adopting sustainable pest management strategies. Integrated Pest Management (IPM) blends biological, cultural, and chemical methods to minimize crop damage and environmental impact. Leveraging beneficial insects for pest control, such as through diverse habitats and biological controls like predatory insects and fungi, presents eco-friendly alternatives to chemical pesticides. Researching and mass-producing effective biological control agents are vital for sustainable pest management practices.

Challenges in Acceptance and Regulation

Despite the potential benefits of using insects in food production, there are challenges to overcome. Cultural acceptance and consumer perception are significant factors that may

influence the adoption of insect-based foods. Many societies have ingrained taboos and aversions towards consuming insects, which can be barriers to widespread acceptance. Additionally, regulatory frameworks governing food safety and labelling often lack clarity on insect consumption. Establishing clear and standardized regulations is necessary to ensure the safety and quality of insect-based food products.

Conclusion

The impact of climate change on insects and their role in food production poses intricate challenges for agriculture. Pest outbreaks, declining beneficial insects, and evolving agricultural landscapes demand innovative, sustainable pest management strategies. Incorporating biological control and supporting natural enemies can reduce reliance on chemical pesticides. Additionally, exploring edible insects as alternative food sources addresses food security and sustainability concerns. Cultural acceptance, regulatory hurdles, and scaling up production are vital considerations. Understanding insect-food-production-environment relationships is crucial for resilient agricultural systems amidst climate change. Collaboration among scientists, farmers, and policymakers is crucial for navigating these challenges and opportunities.

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