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Climate-Resilient Pest Management: Adapting to the New Normal in Agriculture

Biswajit Prusty
Department of Entomology, College of Agriculture,
Odisha University of Agriculture and Technology, Bhubaneswar

Abstract

Climate change is profoundly altering agricultural ecosystems, influencing pest dynamics, host-plant interactions, and the effectiveness of traditional pest control strategies. Rising temperatures, erratic rainfall, and extreme weather events are driving shifts in pest populations, leading to more frequent and severe outbreaks. This article explores climate-resilient pest management strategies, including integrated pest management (IPM), biological control, climate-smart pest forecasting, and the use of resilient crop varieties. By adopting these approaches, farmers can mitigate the risks posed by climate change while ensuring sustainable agricultural production.

Keywords: Climate change, pest dynamics, integrated pest management, biological control, sustainable agriculture, climate-smart strategies.

1. Introduction

Climate change is no longer a distant threat—it is a present-day reality disrupting agricultural landscapes worldwide. With global temperatures rising and weather patterns becoming increasingly unpredictable, pest populations are undergoing significant changes. Warmer temperatures accelerate insect life cycles, expand pest distributions, and alter interactions with host plants and natural enemies (Deutsch et al., 2018). Additionally, climate-induced stress on crops reduces their natural defences, making them more vulnerable to infestations.

Farmers and agricultural scientists are now faced with the challenge of adapting pest management strategies to these new environmental conditions. Traditional chemical-based control methods, though effective in the short term, are proving inadequate due to the rapid evolution of pesticide resistance. This calls for a shift towards climate-resilient pest management approaches that integrate ecological, technological, and predictive tools to safeguard food security.

2. The Impact of Climate Change on Pest Dynamics

Climate change affects pest populations in multiple ways, viz.

2.1. Altered Pest Distribution and Range Expansion:

- Rising temperatures allow pests to expand into previously unsuitable regions.

- For example, the fall armyworm (*Spodoptera frugiperda)*, originally confined to the Americas, has now invaded Africa and Asia due to favourable climatic conditions (FAO, 2021).

2.2. Increased Pest Reproduction and Survival:

- Warmer conditions shorten insect development cycles, leading to more generations per year.
- The brown planthopper (*Nilaparvata lugens*), a major rice pest, has shown increased survival and reproductive rates under higher temperatures (Cohen et al., 2020).

2.3. Disruptions in Natural Enemy-Pest Interactions:

- Climate-induced mismatches between pests and their natural enemies (predators and parasitoids) weaken biological control.
- Studies indicate that elevated CO_2 levels can reduce the efficiency of parasitoid wasps in controlling aphid populations (Thomson et al., 2019).

2.4. Extreme Weather Events and Pest Outbreaks:

- Droughts and floods create favorable conditions for certain pests, such as whiteflies (*Bemisia tabaci*) and locusts (*Schistocerca gregaria*), leading to large-scale outbreaks (IPCC, 2021).

3. Climate-Resilient Pest Management Strategies

To counteract climate-induced pest challenges, agricultural systems must embrace adaptive and sustainable pest management strategies.

3.1. Integrated Pest Management (IPM):

IPM combines multiple pest control approaches to reduce reliance on chemical pesticides while maintaining ecological balance (Kogan, 1998). Key components include:

- Cultural practices: Crop rotation, intercropping, and habitat manipulation to disrupt pest life cycles.
- Biological control: Using parasitoids, predators, and microbial insecticides to regulate pest populations.
- Mechanical control: Traps, barriers, and pheromone-based monitoring systems.
- Chemical control (as a last resort): Using selective and climate-friendly pesticides.

3.2. Climate-Smart Pest Forecasting and Early Warning Systems:

- Remote sensing, artificial intelligence (AI), and big data analytics help predict pest outbreaks based on weather conditions.
- The FAO's Fall Armyworm Monitoring and Early Warning System (FAMEWS) is an example of how digital tools assist farmers in preparing for infestations (FAO, 2021).

3.3. Development of Climate-Resilient Crop Varieties:

- Advances in breeding and biotechnology have led to pest-resistant crop varieties, reducing the need for chemical interventions.
- Bt-cotton, engineered to produce insecticidal proteins, has significantly reduced bollworm infestations (James, 2017).

3.4. Enhancing Agro ecosystem Resilience:

- Diversified farming systems with polycultures and agroforestry can buffer against pest outbreaks.
- Increasing soil health through organic amendments promotes plant resistance to pests.

3.5. Farmer Education and Participatory Approaches:

- Training farmers in climate-resilient pest management techniques ensures effective implementation.
- Community-based pest surveillance programs help in rapid detection and response to outbreaks.

4. Case Studies and Success Stories

4.1. Climate-Smart Pest Management in Rice Farming (India):

- Adoption of alternate wetting and drying (AWD) in rice paddies reduces planthopper infestations by creating unfavourable conditions for egg-laying (IRRI, 2022).

4.2. Push-Pull Technology in Maize Farming (Africa):

- A combination of repellent and attractive plants has successfully controlled stem borers and fall armyworm in Kenya, reducing pesticide dependence by over 50% (Khan et al., 2018).

5. Challenges and Future Perspectives

Despite the effectiveness of climate-resilient pest management strategies, several challenges remain:

- Limited access to advanced technologies in developing countries.
- High initial costs of adopting precision agriculture and biocontrol methods.
- Lack of policy support and financial incentives for sustainable pest management.

Moving forward, interdisciplinary research, farmer-centric policies, and investments in climate-smart agriculture are essential for building resilient food systems.

6. Conclusion

Climate change is reshaping the pest landscape, necessitating a shift from conventional to climate-resilient pest management strategies. By integrating IPM, predictive analytics, biocontrol, and climate-adaptive crop varieties, farmers can mitigate pest threats while promoting sustainable agriculture. Policymakers, researchers, and extension services must work collaboratively to ensure widespread adoption of these practices. Investing in climate-resilient pest management today will secure global food security in the face of future environmental uncertainties.

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