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Impact of Climate Change on Insect Pest Management

Sanhita Chowdhury[1], Sanjay Kumar Sahoo[2], Vinod Kumar Dubey[3] and B. Sujatha[3]
[1]M.Sc. Research Scholar, [2]Associate Professor, [3]Ph.D. Research Scholar, Department of Entomology, Post Graduate College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar

SUMMARY
Increasing atmospheric greenhouse gas concentrations caused by anthropogenically driven climate change are predicted to have a big impact on agricultural pests. Climate change may lead to shifts in geographic distribution, increased overwintering, population growth rates, an increase in the number of generations, an extension of the development season, shifts in crop-pest synchrony, interspecific interactions, pest biotypes, activity and abundance of natural enemies, species extinction, and changes in the effectiveness of crop protection technologies. Additionally, host plant resistance, transgenic plants, natural enemies, biopesticides, and synthetic poisons will no longer be as effective at controlling pests. Therefore, it is necessary to gather data on the expected impacts of climate change on pests in order to create reliable technologies that will work in the future despite global warming and climate change.

INTRODUCTION
Understanding how agro-ecosystems will adapt to climate and change depends on how insects react to environmental change. Although many insect species are damaging to crops, they also serve important functions as parasitoids and predators of significant pest species. An insect population's physiology, biochemistry, biogeography, and population dynamics may change as it moves through its range, moves through different growing seasons, and moves through different types of crops. When insects interact with various competitors, predators, and parasitoids and impose costs at various life stages, their responses to a quickly changing climate may also vary. This may also have an impact on larger food production systems, which may be seriously at danger from the effects of climate change (IPCC 2014). We have to concentrate on the main herbivore pests from the world's major crop-growing regions as well as their main natural adversaries (parasitoids and predators). We evaluate the state of the science on the effects of climate change on pest management, paying particular attention to biologically based techniques (such as Integrated Pest Management, or IPM). The ecological, physiological, and behavioral reactions of organisms are a major area of emphasis in this article. The collapse of trophic interactions and the depletion of ecosystem services could result from changes in the physiological tolerances of species and the population decline of helpful parasitoids and predators, or non-pest competing species. These topics are examined closely throughout the articles, revealing significant knowledge gaps.

Climate Changes Effect on Agro-ecosystems
These "trend effects" (Jentsch *et al.* 2007), such as broad variations in temperature, precipitation, wind, and solar radiation, are being observed all across the world as human impacts on our climate systems are more understood. It is evident from the fifth IPCC report (IPCC 2013) that greenhouse gas emissions, particularly carbon dioxide, are causing sea levels to rise, glaciers to melt, and ocean and air temperatures to rise. These changes are having stronger effects on our weather systems, altering the climates of agro-ecosystems by changing rainfall patterns, changing seasonal averages, and increasing the frequency of severe and extreme weather events.

Impact of Climate Change on Insects
Due to a variety of factors, including dispersal limitations and restrictions brought on by parasitoid/predator/symbiont relationships, many species may not be able to expand or move out their current distribution, and they are essentially stuck within the realized niche and unable to expand into their broader fundamental niche. Microclimate can act as a buffer or amplifier for macroclimate along a variety of axes. Abiotic/biotic, amplification versus buffering, and long versus short temporal and spatial scale axes are some examples of the microclimatic variation axes (Woods *et al.* 2015). Nearby species including social insect nests, insect herbivores are affected by changes in leaf surface temperature and humidity through stomata opening, and leaf miners positioned under the leaf lamina all have an impact on the organisms.

Interactions between species will shift as a result of insects changing their behaviour in search of the best thermal settings. The interactions between the parasitoid *Aphidius rhopalosiphi* (Aphidiidae: Hymenoptera), the main natural adversary of the cereal crop aphid *Sitobion avenae* (Aphididae: Hemiptera), and the two species were altered when the temperature varied by 5°C (Le Lann *et al.* 2014). The maximum rate of Oviposition was seen in parasitoids at the "resting" temperature of 20°C. Aphid metabolic rates and defense against parasitoid attacks increased more when temperatures were raised to 25°C than did those of the parasitoid. As a result, the effectiveness of parasitoid control of aphids may decline. Attacks on mobile species increased along a temperature gradient (from 5°C to 30°C) whereas, attacks on resident prey species remained constant along the gradient in a predator-prey system that included predatory ground beetles (Carabidae), mobile adult prey (*Drosophila*, Drosophilidae: Diptera), and resident prey (a larval Alphitobius, Tenebrionidae: Coleoptera).

Ecological Processes Vital to Plant Protection Impacted by Insect Reactions to Climate Change

Pest Population Dynamics

Plant protection strategies have greatly benefited from the incorporation of thermal biology into the study of insect pest population dynamics, fluctuations, and demographics. Under a hotter and more erratic environment, this research field will continue to offer insights for predicting pest outbreaks in the next decades (Bale and Hayward 2010; Colinet *et al.* 2015). Days with high temperatures are prevailing more frequently in agricultural crop areas. Different developmental stages are being exposed to extremely hot temperature events that may affect insect pest ontogeny, preventing maturity and altering adult reproduction, feeding, and growth rates.

Pest–Crop Plant Interactions

With altered CO_2 concentrations, high temperatures, and more variable moisture regimes, it is anticipated that the nutritional quality of agricultural goods would vary. These changes will be complex, notably in terms of palatability for insect pest species. For instance, the Japanese beetle, *Popillia japonica* (Scarabaeidae: Coleoptera) caused herbivore damage by altering the key hormone signalling pathways of jasmonic acid (JA), salicylic acid (SA), and ethylene before and after the damage.

Intraguild Predation

When a parasite or predator targets both the host or prey species that it is believed to be the main target of biocontrol (such as the pest), as well as consuming other parasites or predators in the system, this is known as intragular predation. Increased temperature (+2°C) has resulted in rising predator abundance (carabid beetles) in a spring-sown wheat crop, but a 10% precipitation increase caused no change in the predator’s abundance (Berthe *et al.* 2015).

Tritrophic Interactions

Host plant and herbivore dynamics influence parasitoids as part of a complex of interactions, and climate change will have a significant impact on these interactions (Facey *et al.* 2014). Stireman *et al.* (2005) examined interactions between caterpillars and parasitoids in 15 databases spanning from central Brazil to Canada. They discovered that capacity of parasitoids to monitor host population declines as climatic variability rises.

Pest–Pathogen Interactions

In particular, their contribution to lowering global food security and their unfavourable interactions with CO_2 fertilization have received very little attention as part of climate change impacts (Chakraborty and Newton 2011; Juroszek and Von Tiedemann 2013). It is expected that, as the geographical ranges of pests start to shift, the pathogens associated with these pests will also move into new regions, exposing different crop varieties to a range of new viruses and phytopathogens that are transferred by insect pests.

Climate Change and Insect Pests Management Approaches

Changes in insect-plant interactions and IPM regimes will be significant and less predictable due to rising CO_2 levels, temperatures, fluctuating precipitation, and the spread of non-native insect species**.** Because many insect pest species are ectotherms (or regional heterotherms), their internal temperatures vary widely, and they respond quickly to temperature increases, it is generally expected that insect chewing herbivores will consume more leaf tissue as plant nutrition is reduced (more carbon per unit of nitrogen). Pest (and pathogen) attack will likely become more unexpected and have higher amplitude as a result of a changing climate and more erratic weather patterns. The interactions between insects and plants in this system and their effects on crop productivity are yet unknown, in addition to the uncertainties surrounding how climate change may directly affect crop yields (Gregory *et al.* 2009).

Glasshouse pests may pose a greater threat in open fields and pastures as a result of one important ecosystem shift. It is also believed that short-lived animals, such as insect pests, may experience increased population growth and longevity. One of the main factors contributing to the growth of insect pests into new locations and a prolonged growing season in existing regions may be relaxed cold limitation (Diffenbaugh *et al.* 2008).

It will be necessary to alter farming practices and implement adaptive management techniques to lessen the effect that agricultural pests have on crops (Thomson *et al.* 2010). To reduce vulnerability to pest outbreaks, this may involve: (1) planting a variety of plants; (2) planting at various times of the year; and (3) widening the diversity of habitat on the edges. At the farm size, all of these tactics are employed to reduce pest effect. Mulching, raised beds and shelters to save soil moisture, safeguarding crops from severe rains, high heat, and flooding, and preventing soil deterioration are some very easy methods.

CONCLUSION

Under a changing climate, insect pests are likely to become more damaging, especially if the current worldwide broad-spectrum spraying regimes continue. This requires a greater understanding of pest population dynamics, thermal physiology, ecology, behaviour and core IPM priorities of host plant resistance, area-wide management, emergency chemical control when required, and predictive modelling tools when controlling pests in a more variable climate. A more holistic inclusion of different management regimes including resistant cultivars, preservation of natural enemy activity, utilizing thresholds, use of pheromones, use of selective insecticides in preference to broad-spectrum usage, landscape manipulation, tillage management, crop rotation, biological control (naturally occurring and safely introduced, classic, mass-reared natural enemies) within an adaptive management context will be critical for managing insect pests in agro-ecosystems within a rapidly changing climate.

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