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Impact of Climate Change on Insect Pests and Their Management Strategies

Deepak Tomar[0], Ali Khan[1], and Abdullah Zaid[2]
[0]M.Sc. Research Scholar, Department of Entomology, College of Agriculture, Banda University of Agriculture and Technology, Banda Uttar Pradesh
[1]M.Sc. Research Scholar, Department of Plant Pathology, College of Agriculture, Banda University of Agriculture and Technology, Banda Uttar Pradesh
[2]M.Sc. Research Scholar, Department of Fruit Science, College of Horticulture, Banda University of Agriculture and Technology, Banda Uttar Pradesh

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Introduction

Climate change and global warming are of great concern to agriculture worldwide and are among the most discussed issues in today's society. Climatic parameters such as increased temperatures, rising atmospheric CO_2 levels and changing precipitation patterns have created significant impacts on agricultural production and on agricultural insect pests. Changes in climate can affect insect pests in several ways. They can result in an expansion of their geographic distribution, increased survival during overwintering, increased number of generations, altered synchrony between plants and pests, altered interspecific interaction, increased risk of invasion by migratory pests, increased incidence of insect-transmitted plant diseases, and reduced effectiveness of biological control, especially natural enemies. As a result, there is a serious risk of crop economic losses, as well as a challenge to human food security. As a major driver of pest population dynamics, climate change will require adaptive management strategies to deal with the changing status of pests. Several priorities can be identified for future research on the effects of climatic changes on agricultural insect pests. These include modified integrated pest management tactics, monitoring climate and pest populations, and the use of modelling prediction tools.

Climate under Change

The climate is a crucial element that determines various characteristics and distributions of managed and natural systems, including hydrology and water resources, cryology, marine and freshwater ecosystems, terrestrial ecosystems, forestry and agriculture. It can be explained as the phenomenon that involves changes in environmental factors such as temperature, humidity and precipitation over many years. As a result of increased

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temperatures, climate extremes, increased CO_2 and other greenhouse gases (GHGs) as well as altered precipitation patterns, global food production is under severe threat. Global warming is a serious problem facing the world today. It has reached record breaking levels as evidenced by unprecedented rates of increase in atmospheric temperature and sea level. According to the World Meteorological Organization (WMO), the world is now about one degree warmer than before widespread industrialization. The Intergovernmental Panel on Climate Change (IPCC) also reported that each of the last three decades has been increasingly warmer, with the decade of the 2000s being the warmest. Based on a range of global climate models and development scenarios, it is expected that the Earth could experience global warming of 1.4 to 5.8^0 C over the next century. The main cause of global warming is increased concentrations of greenhouse gases in the atmosphere. The most prevalent atmospheric gases are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are caused by many anthropogenic activities including burning off the fossil fuels and land-use change. Looking at the period of industrialization in the last two centuries, the concentration of greenhouse gases has increased immensely compared to the pre-industrial era. Among the greenhouse gases, CO_2 is the most important and the most abundant. The increase in atmospheric CO_2 is one of the most recorded global changes in the atmosphere in the last half century. Its concentration in the atmosphere has increased dramatically to 416 PPM, against 280 PPM reported from pre-industrial period, and is likely to double in 2100 century.

The climatic change impact on pests in various ways such as:

Changes in diversity and abundance of insect pests, Changes in geographical distribution of insect pests, Increased overwintering insects, Rapid population growth and no. of generations, Changes in synchrony between insect pests and their host crops, Introduction of alternative hosts plants, Changes in host plant resistance, Changes in insect biotypes,Changes in tritrophic interactions, Impact on extinction of species, Changes in activity and relative abundance of natural enemies, Increased risk of invasive pest species andReduced efficacy of crop protection technologies. In Fig.1 insects decline data over the past decade has been represented.

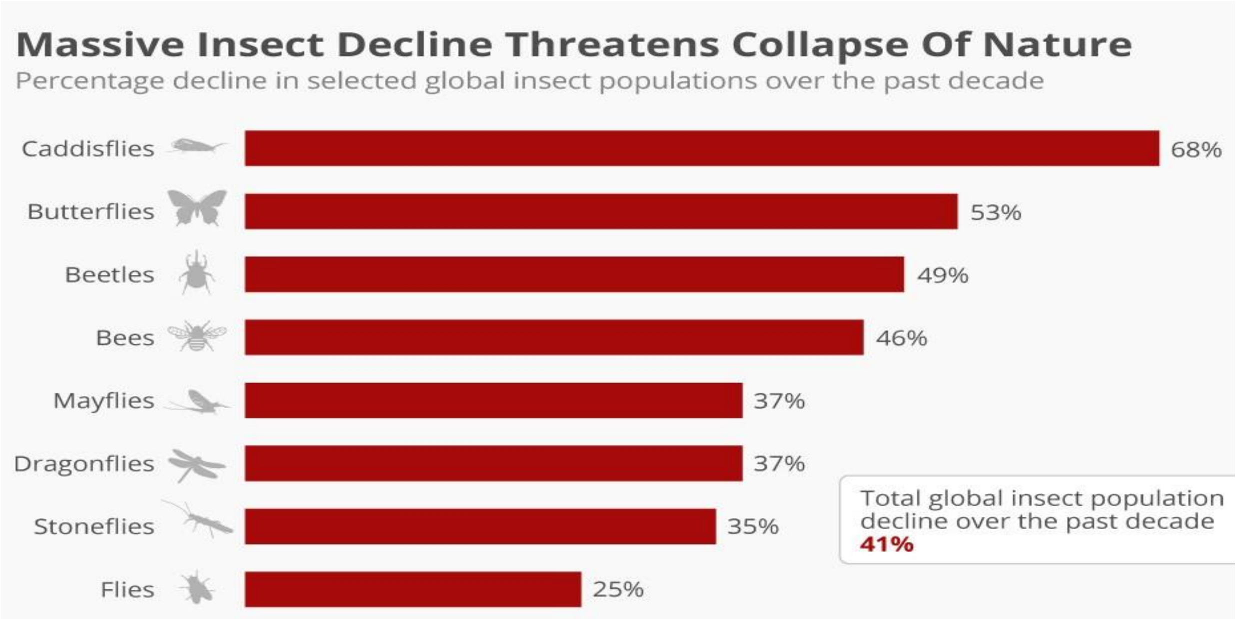

Fig.1 source: Biological Conservation 2019

Response of Insect Pests to Increased CO_2

Elevated concentrations of atmospheric CO_2 can affect the distribution, abundance, and performance of herbivorous insects. Such increases can affect consumption rates, growth rates, fecundity, and population densities of insect pests. Currently available data suggest that the effect of elevated atmospheric CO_2 on herbivory is not only highly specific to individual insect species, but also to particular insect pest–host plant systems. The effects of increasing CO_2 levels on insect pests are highly dependent on their host plants. Increased CO_2 levels would have a greater impact on C3 crops (wheat, rice, cotton, etc.) than on C4 crops (corn, sorghum, etc.). Therefore, these differential effects of elevated atmospheric CO_2 on C3 and C4 plants may result in asymmetric effects on herbivory, and the response of insects feeding on C4 plants may differ from that of C3 plants. C3 plants are likely to be positively affected by elevated CO_2 and negatively affected by insect response, whereas C_4 plants are less responsive to elevated CO_2 and therefore less likely to be affected by changes in insect feeding behavior. Furthermore increased CO_2 levels are likely to affect plant physiology by increasing photosynthetic activity, resulting in better growth and higher plant productivity. This in turn would indirectly affect insects by changing both the quantity and quality of plants and vegetation. A common feature of plants grown under elevated CO_2 is a change in the chemical composition of leaves, which could affect the nutrient quality of foliage and palatability to leaf-feeding insects

Response of Insect Pests to Increased Temperature

Insect physiology is very sensitive to changes in temperature, and their metabolic rate tends to approximately double with an increase of 10^0C. In this context, many researchers have shown that increased temperature tends to accelerate insect consumption, development, and movement, which can affect population dynamics by influencing fecundity, survival, generation time, population size, and geographic range. Species that cannot adapt and evolve to increased temperature conditions generally have a difficult time maintaining their populations, while other species can thrive and reproduce rapidly. Temperature plays an important role in metabolism, metamorphosis, mobility, and host availability, which determines the possibility of changes in pest population and dynamics. From the distribution and behavior of contemporary insects, it can be hypothesized that rising temperatures should be accompanied by increased herbivory. Given the distribution and behavior of insect pests, it can be hypothesized that an increase in temperature should be associated with increased herbivory, as well as changes in the growth rate of insect populations. Thus, insect populations in tropical zones are predicted to experience a decrease in growth rate as a result of climate warming due to the current temperature level, which is already close to the optimum for pest development and growth, while insects in temperate zones are expected to experience an increase in growth rate.

Response of Insect Pests to Changeable Precipitation Pattern

Changes in the amount, intensity, and frequency of precipitation are very important indicators of climate change. As observed in most events, the frequency of precipitation has decreased while the intensity of precipitation has increased. This type of rainfall pattern has favored the occurrence of droughts and floods. Insect species that overwinter in the soil are directly affected by overlapping rainfall. In short, heavy rainfall can lead to flooding and prolonged stagnation of water. This event threatens insect survival and at least affects their diapause. In addition, insect eggs and larvae can be washed away by heavy rains and flooding. Small-bodied pests like aphids, mites, jassids, whiteflies etc. can be washed away during heavy rainfall. Variable rainfall can have a major impact on insect populations. For examplewireworms are very damaging pests of crops such as potatoes, corn, sugar beet, etc, especially when grown in grassland plots, and there are predictions that they are likely to become a much greater problem with the effects of climate change. Herbivorous insects are affected by drought through several mechanisms, dry climates may provide suitable environmental conditions for the development and growth of herbivorous insects.

Impact of Climate Change on Pollinators and Pollination

Insects play vital role in providing various ecosystem services. One of the very important is pollination as they are excellent pollinators for many of the economically important crops. Approximately 73 per cent of the world's cultivated crops are pollinated by bees, 19 per cent by flies, 6.5 per cent by bats, 5 per cent by wasps, 5 per cent by beetles, 4 per cent by birds, and 4 per cent by butterflies and moths. According to Millennium Ecosystem Assessment report 2005, pollination is one of the 15 major ecosystem services currently under threat from mounting pressures exerted by growing population, depleting natural resource base and global climate change. Earlier studies have clearly shown that the population abundance, geographic range and pollination activities of important pollinator species like bees, moths and butterflies are declining considerably with changing climate. The climatic factors like temperature and water availability have been found to affect profoundly the critical events like flowering, pollination and fruiting in the life cycle of plants. Many pollinators have synchronized their life cycles with plant phenological events. Impending climate change is expected to disrupt the synchrony between plant-pollinator relationships by changing the phenological events in their life cycles and may thus affect the extent of pollination.

Strategies to mitigate the effects of climate change

Shifts in species abundance and diversity due to climate change may result in reduction in the efficacy of insect pest management programs; hence the need to sharpen existing monitoring tools and develop new ones to help detect potential changes in pest distribution, population ecology, damage assessment, yield loss and impact assessment. Potential changes in pest survival strategies may need broader and stronger inter-center partnerships to develop new IPM options or disseminate existing ones to new areas where farmers may find these applicable. Current sensitivities on environmental pollution, human health hazards and pest resurgence are a consequence of improper use of synthetic insecticides. Several botanically and biologically based products are presently used as environmentally friendly products. However, many of these methods of pest control are highly sensitive to the environment. Increase in temperatures and UV radiation, and a decrease in relative humidity may render many of these control tactics to be ineffective. Therefore, there is a need to develop appropriate strategies for pest management that will be effective under situations of global warming in future. Host-plant resistance, natural plant products, bio-pesticides, natural enemies, and agronomic practices offer a potentially viable option for integrated pest management. But, the relative efficacy of many of these control measures is likely to change as a result of global warming. Biological control which is considered as the important and effective component of IPM programs is severely affected by climate change, since the relationship between natural enemies and host pests will be affected. Almost all the insect control methods including cultural practices, natural enemies, host plant resistance, bio pesticides, and synthetic pesticides are highly sensitive to the environment. Thus a more robust and climate adaptable pest management technologies are needed for managing insect pests. For sustainable agriculture and to mitigate the climate effects on agriculture, evaluating the effects of climate change on crop production and development of climate smart crops is important. Climatic and crop models need to be developed for land use criteria, and soil productivity and the methods for tailoring insecticide/herbicide inputs to weather need to be developed. Further, advanced cropping methods and cropping systems is needed that would reduce the risk of attack/competition need to be explored. The alarming point is the transition of insect pests to new territories in absence of natural enemies as it will lead to pest outbreaks. The main challenge ahead is to develop successful prediction models that would pave way for their management. An urgent need is felt to develop and adopt modeling strategies to predict the changes in geographical distribution and population dynamics of insect pests and the strategies to be adapted to reduce crop losses.

Conclusion

Warmer temperatures, changes in precipitation, increased drought frequency and higher CO_2 concentrations due of climate change will have a devastating effect on abundance of insect pests, which might lead to the emergence of new pests. It is likely that if measures and global collaborative efforts are not undertaken, most pests will have a cosmopolitan range wherever the climate is favorable and the hosts are available. Further, pest control strategies such as host plant resistance, biological control, synthetic insecticides, etc., may be rendered less effective. Understanding insect-plant interactions, efficacy of natural enemies, host plant resistance, bio pesticides and synthetic insecticides under climate change need to be studied carefully to devise appropriate methods for pest management.