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Impact of Climate Change on Agricultural Insect Pests

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Global climate change has a substantial impact on agriculture, as well as agricultural insect pests. Climate change has both direct and indirect effects on agricultural crops and pests. Climate change has direct effects on the reproduction, development, survival, and dissemination of pests, while it has indirect effects on the interactions between pests, their surroundings, and other insect species, including competitors natural enemies, vectors, and mutualists. Insects are poikilothermic organisms, meaning that their body temperature is determined by the temperature of their environment. Therefore, the most significant environmental element influencing insect behavior, dispersal, development, and reproduction is most likely temperature. As a result, it is extremely likely that the main drivers of climate change (increasing atmospheric CO2, increased temperature, and decreased soil moisture) would have a considerable impact on insect pest population dynamics and consequently the proportion of crop losses. Climate change produces new ecological niches, allowing insect pests to establish and proliferate in new geographic areas, as well as shift from one to another. Rising temperatures and CO_2 can have a significant impact on interactions between agricultural crops and insect pests due to the complexity of their physiological impacts. Farmers can expect new and intense insect problems in the coming years as the climate changes.

Impact of Climate Change on Insect Pests

1. Response of Insect Pests to Increased Temperature: The physiology of insects is extremely sensitive to temperature fluctuations; an increase of 10 ˚C tends to double their metabolic rate. Temperature increases tend to speed up insect movement, development, and consumption, which can impact fecundity, survival, generation time, population size, and geographic range, among other aspects of population dynamics.Temperature affects metabolism, metamorphosis, movement, and host availability, influencing pest population dynamics. It can be inferred from the distribution and behavior of modern insects that herbivory should increase in response to rising temperatures. Because soil is a thermally insulating substance that can buffer temperature changes and lessen their impact, insects that spend the majority of their life cycle in the soil are less affected by rising temperatures than aboveground insects. The rate of increase in global temperatures in the upcoming years will determine future changes in insect population dynamics. Global warming scenarios are predicted to increase the severity of pest infestations as ambient temperatures tend to rise toward ideal levels for the growth and development of many insect pest species, potentially lowering thermal limitations on population dynamics.

2. Response of Insect Pests to Increased CO2 Concentration: The distribution, abundance, and performance of herbivorous insects can all be impacted by elevated atmospheric CO2 concentrations. These increases may have an impact on insect pest population densities, fecundity, growth rates, and consumption rates. The impact of rising CO2 levels on insect pests is mainly dependent on the plants that serve as their hosts. C3 crops (wheat, rice, cotton, etc.) would be more affected by rising CO2 levels than C4 crops (corn, sorghum, etc.). Nitrogen is a critical component in the insect's body for development, hence higher CO2 concentration leads to increased plant consumption rates in particular pest groups. Pests must consume more plant tissue to receive a similar amount of food, which can result in increasing levels of plant damage. In foliage feeders, including miners, chewers, and caterpillars, increased consumption rates are frequently the result of compensatory eating in response to a decrease in nitrogen, as predicted by CO2 fertilization.

3. Response of Insect Pests to Changeable Precipitation Pattern: Changes in precipitation quantity, intensity, and frequency are crucial indicators of climate change. The frequency of precipitation has reduced while its severity has increased, as is the case with most events. Overlapping rainfall has a direct impact on insect species that overwinter in the soil. In short, significant rainfall can cause floods and long-term stagnation of water. This event threatens insect survival and, at the very least, interferes with diapause. Additionally, flooding and severe rains can wash away insect eggs and larvae. Small-bodied pests such as aphids, mites, jassids, and whiteflies can be washed away after heavy rains. Insect populations can be significantly impacted by variable rainfall.

4. Expansion of Insect's Distribution: Climate change will have a substantial impact on the geographic spread of insect pests, with low temperatures are frequently more important to high temperatures in determining their geographic distribution. Species-specific climatic requirements that are essential to their growth, development, reproduction, and survival show the geographical distribution and abundance of all organisms in nature. Modified temperature and precipitation patterns due to predicted climate changes will impact species distribution, survival, and reproduction in the future. Farmers will face new and severe pest problems when insects spread to new locations and the growing zones of their host plants alter.

5. Increased Overwintering Survival: Insects are poikilothermic, or cold-blooded, and hence have limited ability to maintain homeostasis in response to variations in ambient temperature. They have developed a range of techniques to survive in thermally challenging environments. Insects are typically divided into two categories based on their overwintering tactics: freeze-tolerant and freeze-avoidant. The first group of insects use a physiological adaptation mechanism known as diapause, whereas the second group uses a behavioral avoidance or migration. Diapause is a hormonally mediated condition of low metabolic activity that can occur in insects and is characterized by repressed development, suspended activity, and greater tolerance to unfavorable environmental extremes. Diapause is an adaptive characteristic that regulates insect life cycles seasonally and is controlled by environmental conditions like temperature, photoperiod, and humidity. There are two types of diapause: aestivation and hibernation. Aestivation permits insects to survive in higher temperatures, whereas hibernation keeps them alive in lower temperatures.

6. Increased Number of Generations: In a global warming scenario, this allows for faster reproduction rates within a specific favored range, increasing the number of generations of many insect species and causing more crop damage. Growing degree days (GDD) are a measure of thermal development tolerance, one of the many species features and climate variables that have been used to connect climate change to phenological changes. A measure of heat accumulation known as GDD is determined annually to include up all of the degrees that fall between a minimum and maximum temperature threshold (Dmin and Dmax). In agriculture, GDD has long been utilized to forecast the phenology of plants and insects. Future temperature increases will have differing effects on univoltine and multivoltine temperate species.

7. Reduced Effectiveness of Biological Control Agents—Natural Enemies: Climate change is expected to have a significant impact on the abundance, distribution, and seasonal timing of pests and their natural enemies, altering the effectiveness of biological control methods. Both top-down (natural enemies) and bottom-up (host plant availability and quality) mechanisms naturally regulate phytophagous insect species. Insect behavior, performance, and population dynamics are influenced by the interaction of these natural processes.

Phytophagous insects are important components of the tritrophic host-insect pest-natural enemy connection in agricultural, forestry, and other ecosystems. Climate change is projected to cause shifts in crop distribution ranges. Spatial desynchronization may emerge from herbivores tracking shifts in food distribution and migrating to locations where their predators or parasitoids may or may not be tracking them. The final outcome is partially determined by the ability of related natural enemy species to expand their geographic range, as well as the possibility of new natural enemy populations that can control the pest in its new habitat. In the absence of these conditions, herbivores may be able to avoid predation and establish enormous populations in their new habitat.

8. Increased Incidence of Plant Diseases Transmitted by Insect Vectors: Insects are significant vectors for numerous plant diseases, including viruses, phytoplasmas, and bacteria. Viruses are the most common cause of plant diseases in global food production. Viruses depend severely on their vectors for transmission and spread since they are immobile outside of their vector or host insect. Some viruses and vectors are host generalists and others are specialists with a specific mode of transmission. Climate change could have significant effects on the epidemiology of plant viruses. The majority of agricultural crop viruses are single-stranded DNA and messenger RNA viruses. They mostly use insect vectors with piercing and sucking mouthparts to spread from host to host. The climate may have an indirect impact on the viruses that insects spread because it has a direct impact on their physiology, phenology, etc. This influence may have a positive, negative, or neutral impact on the establishment and spread of viral infections in crop production.

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