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Effects of global warming on insect behaviour in agriculture

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Abstract: Global warming and climate change are some of the most widely discussed topics in today's society, and they are of considerable importance to agriculture globally. Climate change directly affects agricultural production. On the other hand, the agricultural sector is inherently sensitive to climate conditions, and this has made the agricultural sector one of the most vulnerable sectors to the effects of global climate change. Rising CO_2 levels in the atmosphere, increased temperature, and altering precipitation patterns all substantially influence agricultural insect pests and agricultural productivity. Climate change has a number of implications for insect pests. They can lead to a decreased biological control effectiveness, particularly natural enemies, increased incidence of insect-transmitted plant diseases, increased risk of migratory pest invasion, altered interspecific interaction, altered synchrony between plants and pests, increase in the number of generations, increased overwintering survival, and increase in geographic distribution. As a consequence, agricultural economic losses are a real possibility, as is a threat to human food and nutrition security. Global warming will necessitate sustainable management techniques to cope with the altering state of pests, as it is a primary driver of pest population dynamics. Future studies on the impacts of climate change on agricultural insect pests might be prioritized in several ways. Enhanced integrated pest control strategies, the use of modelling prediction tools, and climate and pest population monitoring are only a few examples.

Keywords: agriculture, climate change, food security, global warming, insect pests

INTRODUCTION

Many changes in everyday life, culture, science, technology, the economy, and agricultural output have accompanied human population expansion throughout history. Agricultural output has experienced several important transformations, or agricultural revolutions, as a result of the rise of civilisation, technology, and overall human progress [Christiaensen, Martin 2018]. However, the extraordinary population expansion over the previous hundred years has had a number of negative repercussions that (in addition to changes in the environment) have harmed food security [Kuiper, Cui 2021]. Growing worldwide population means increased food production demands; as a result, global agricultural output will almost certainly need to be doubled by

2050 to fulfill that expectation [Pastor *et al.* 2019]. Increasing agricultural productivity instead of clearing the additional land area for crop production seems to be the most sustainable method for food security, according to several studies [Christiaensen, Martin 2018; Pastor *et al.* 2019].

Global warming and associated phenomena, such as droughts, violent storms, flooding, heatwaves, CO_2 concentrations in the atmosphere, and rising global temperature and other extreme weather occurrences, are the subject of modern scientific study and agronomy [Cogato *et al.* 2019]. As a result, agricultural research is paying increasing attention to the abiotic variables described above as the desire to decrease yield loss due to such circumstances grows. Variations in precipitation patterns may be more important than rising temperature in terms of crop productivity, particularly in places where droughts are a limiting factor [Panda, Sahu 2019]. Pests, which are similarly influenced by climate change and weather disturbances, are one of the most important biotic elements. The reproduction, survival, spread, and population dynamics of pests, as well as the interactions among pests, the ecosystem, and natural enemies, are all directly affected by rising temperature. As a result, it's critical to keep an eye on the presence and quantity of pests, as circumstances for their occurrence might alter quickly [Canelles *et al.* 2021; Chen *et al.* 2019]. The impact of some of the anticipated climatic changes, notably growing CO_2 levels and temperature in the atmosphere, as well as shifting patterns of precipitation, on the ecology and biology of dangerous insects, in particular invasive pest species, that can be a serious issue in agricultural productivity, will be discussed in this paper. Plant production concerns will be discussed, as well as possible remedies, often in the form of integrated pest management (IPM) strategies. IPM and ecologically friendly food production, as well as modelling prediction tools and monitoring approaches, are among the topics covered.

THE CHANGING CLIMATE

Climate is an important factor influencing the distributions and features of both natural and controlled systems, including agriculture and forestry, terrestrial ecosystems, freshwater, and marine ecosystems, cryology, water, and hydrology resources [Afshar *et al.* 2021; Finch *et al.* 2021; Nourani *et al.* 2019; 2020; Saxena *et al.* 2021]. It's a phenomenon caused by long-term variations in climatic variables, including precipitation, humidity, and temperature. Global food production has been under serious threat as a consequence of elevated temperature, changing precipitation patterns, rising CO_2 and other greenhouse gases (GHGs), and climatic extremes. Global warming is a major issue that the planet is now dealing with [Finch *et al.* 2021]. As shown by extraordinary rates of growth in air temperature and sea level, it has reached record-breaking levels. According to the World Meteorological Organization (WMO), the world is presently almost one degree warmer than it was before extensive industrialisation, according to the WMO. According to the Intergovernmental Panel on Climate Change (IPCC), every one of the past three decades has become warmer, with the 2000s being the warmest. According to a variety of international climate models and development prospects, the Earth may warm by 1.4–5.8°C during the next century [Molajou *et al.* 2021a, b]. Elevated levels of GHGs in the atmosphere are the primary cause of global warming. Nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) are the most common atmospheric gases, and they are generated by a variety of anthropogenic activities such as fossil fuel combustion and territory change.

In comparison to the pre-industrial period, the amount of greenhouse gases has grown dramatically throughout the period of industrialisation in the previous two centuries. CO_2 is the most significant and plentiful of the greenhouse gases. One of the most well-documented worldwide changes in the atmosphere in the previous half-century has been the increase in atmospheric CO_2. Its levels in the atmosphere have risen rapidly to 416 parts per million (ppm), compared to 280 ppm in the pre-industrial era, and is expected to double by 2100 [Canelles *et al.* 2021; Möller 1963]. Heatwaves are anticipated to become more common and remain longer, as well as more frequent and intense extreme precipitation events in some regions [Saxena *et al.* 2021]. The precipitation trend will most likely shift and, therefore, will not be uniform. There seems to be a rise in yearly precipitation in higher latitudes and in the equatorial Pacific. Average precipitation is expected to drop in the dry mid-latitude and subtropical areas, whereas it is likely to increase in the wet mid-latitude regions. Severe weather conditions are anticipated to become more frequent and stronger in most mid-latitude locations and wet tropical regions. To tackle the difficulties provided by the negative consequences of climate change, the UN (United Nations) and the IPCC have taken several decisions to cut GHGs emissions, offer financial support to developing nations, and increase adaptive ability.

INSECT PESTS AND CLIMATE CHANGE

Agriculture, as well as agricultural insect pests, are affected significantly by global climate change. Climate change has a direct and indirect impact on agricultural crops and the pests that attack them. Climate change has direct effects on pest spread, survival, development, and reproduction, while it has indirect effects on the interactions between pests, their environment, and other insect species, including mutualists, vectors, rivals, and natural enemies. Insects are poikilothermic, meaning their body temperature is affected by the temperature of their surroundings [Zeng *et al.* 2020]. Insect reproduction, development, dispersion, and behaviour are all influenced by temperature. As a result, the primary causes of climate change (decreased soil moisture, increased temperature, and increased atmospheric CO_2) are extremely likely to have a large impact on insect pest population dynamics and, as a result, agricultural losses [Diffenbaugh *et al.* 2008]. Global warming generates new ecological niches, allowing insect pests to develop and proliferate in new territories and states and migrate from one to the next. The complexities of physiological changes caused by increasing CO_2 and temperature can significantly impact agricultural crop-insect pest interactions [Deutsch *et al.* 2018]. As a result of the changing environment, farmers may expect to confront new and more severe insect issues in the future years.

INSECT PESTS' REACTIONS TO RISING TEMPERATURE

Insect physiology is extremely sensitive to temperature fluctuations, and a 10°C increase in temperature causes their metabolic rate to nearly double [Lehmann *et al.* 2020; Ma *et al.* 2021].

Numerous studies have found that rising temperature hastens insect-eating, development, and migration, which could have an impact on population dynamics by altering geographic range, population size, generation time, survival, and fecundity [Harvey *et al.* 2020]. Creatures that are unable to adjust and develop in response to rising temperature have a tough time sustaining their numbers, whilst others flourish and reproduce fast. Temperature affects metabolism, metamorphosis, movement, and host availability, all of which influence pest population and dynamics [Deutsch *et al.* 2018].

It may be assumed that increases in temperature will be followed by greater herbivory based on the behaviour and distribution of current insects [Jactel *et al.* 2019]. Due to the behaviour and distribution of insect pests, it's reasonable to assume that rising temperature will result in greater herbivory and changes in insect population growth rates. And hence, considering the current temperature level, which has been close to the optimum for pest growth and development, insect populations in tropical zones are anticipated to witness a decrease in growth rate as a result of climate warming, whereas insect populations in temperate zones are bound to undergo an increase [Gely *et al.* 2020]. The same researchers validated this idea by calculating insect population increase in the output of the world's three primary grain crops under various climate change scenarios [Rasche 2021]. Because soil is a thermally insulating material that may buffer temperature fluctuations and therefore decrease their impact, the impacts of increasing temperature are larger for aboveground insects than for species who spend most of their life cycle in the soil [Pathak *et al.* 2021].

INSECT PESTS' REACTIONS TO RISING CO_2 LEVELS

The range, number, and behaviour of herbivorous insects can be influenced by elevated CO_2 levels in the atmosphere [Lincoln *et al.* 1993]. Insect pests' intake, fecundity, growth, and density of population can all be affected by such increases. Based on current evidence, the impact of rising atmospheric CO_2 on herbivory is unique to both individual species of insects and insect pest–host plant systems. Insect pests' responses to rising CO_2 levels are greatly reliant on the plants that serve as their hosts [Stacey, Fellowes 2002]. C3 crops would be impacted more than C4 crops by increased CO_2 levels. As a product of these asymmetric effects of increased atmospheric CO_2 on C4 and C3 plants, insects feeding on C4 plants might react differently than insects feeding on C3 plants. High CO_2 is expected to benefit C3 plants while insect reaction is likely to harm them, but C4 plants are less sensitive to CO_2 and hence less likely to be influenced by variations in insect feeding habits [Jabran *et al.* 2020]. Elevated CO_2 concentrations are expected to impact plant physiology by boosting photosynthetic activity, leading to plant productivity and improved growth, as indicated in the preceding section. Insects would be harmed indirectly as a result of the change in vegetation and plant quality, and quantity [Tan *et al.* 2021]. A shift in the chemical structure of leaves is a typical characteristic of plants growing under high CO_2, and it can impact the nutritional quality of foliage as well as the palatability of leaves to leaf-feeding insects [Hussain *et al.* 2021].

CONCLUSIONS

While there are many unknowns about global warming, it is commonly acknowledged that it significantly impacts agricultural plant production and insect infestations. Small-scale climatic variability, such as relative humidity, shifting precipitation patterns, increases in atmospheric CO_2, temperature increases, and other variables, are some of the uncertainties surrounding various elements of climate change that are important to insect pests. Because of the great diversity of species of insects, their host plants, and worldwide climate changes, species of insects are predicted to respond to climate change in a variety of ways in various regions of the globe. Global warming has a mixed effect on insects, favouring some and hindering others when affecting their range, variety, quantity, maturation, phenology, and growth. Furthermore, an overall rise in the incidence of pest infestations encompassing a larger spectrum of insect pests is predicted. Insects would very certainly increase their global range. The abundance of some pests will grow as a result of improved overwintering survival and the capacity to generate additional generations. Invasive pest species would most likely spread faster in new regions, and insect-transmitted plant illnesses will become more common. We stand a serious danger of major economic losses and a threat to human food security if climate change variables lead to favourable circumstances for insect infestation and crop destruction. To address this issue, we will need to take a proactive and scientific approach.

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