Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 03, Issue: 05 (SEP-OCT, 2023)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Dynamism of IPM under Changing Cropping System and Climate

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Climate change is the progressive rise in the average temperature of the Earth's atmosphere and oceans, which causes a permanent change in the climate. Since 1900, the average worldwide temperature has risen by 1°C, with northwest North America experiencing the most increase. India's temperature has risen by 0.2°C to 1°C during the same period. Temperatures have risen twice as quickly in the last 50 years as they did in the previous 100 years, signaling an acceleration in the rate of global warming. In India, the average temperature may rise by as much as 3.2°C in rabi (November-March) and up to 1.7°C during kharif (July-October). By 2070, rainfall is projected to rise by 10% as well (Gupta, 2011). Crop output and agricultural pests are significantly impacted by climate change and extreme weather. The effects of increasing temperatures, CO^2 concentrations, and precipitation patterns on agricultural insect pests are covered in this article. Since temperature affects insect population dynamics, warming of the environment may result in changes in how insects interact with host plants and natural enemies, as well as a geographic extension of their range and an increase in overwinter survival. Future pest management techniques, such as monitoring the climate and pest populations, adapting integrated pest management techniques, and using modelling prediction tools, will be necessary as the pest problem gets worse.

Scenario of impact of climate change

1. India has more challenges from the effects of impending climate change because it is a tropical nation. By the end of the next century, the average global temperature is predicted to have risen by 1.1–5.4°C over the previous 100 years.
2. In addition to having direct effects on plant yield, climate change can also have indirect consequences via changes in diseases and pests.
3. Climate change-driven global warming is affecting many species, including insect species, in terms of distribution, demography, and life histories. It is also having an impact on insect phenology, including arrival and emergence timings for a variety of insects.

India, a tropical country, will experience several difficulties as a result of the upcoming climate change. Over the past century, the average global temperature has increased by 0.8°C, and by the end of the next century, it is expected to have increased by 1.1–5.4°C. In addition, CO_2 levels in the atmosphere have risen sharply from 280 parts per million to 370 parts per million and are projected to double. In addition to having a direct impact on plant yield, climate change has the potential to have an indirect impact thanks to changes in pests and diseases. The principal contenders that are greatly impacted by climate change are the insect pests that attack agriculture plants.

Impacts of climate change on insect pests

Insects' behavior, distribution, development, survival, and reproduction are influenced by temperature, which is the most important environmental factor for them. Anthropogenic CO_2 contributes more to temperature increase than other greenhouse gases combined.

Effects of elevated CO_2 on insect pests

In general, it may be said that host plants grown in high carbon dioxide environments demonstrate a decreased nutritional value to insect herbivores, which affects their behaviour and productivity. The nutritional value of the leaf material that the insects eat declines as a result of the phenotypic changes in the host plants. As a result, insects have a harder time turning the food they eat into biomass. Insect herbivores frequently increase their food intake to make up for the impacts of poor nutrition.

The nitrogen levels found in the leaves have a positive correlation with how well insect herbivores operate. According to Zvereva and Kozlov's (2010) research, mustard and collard leaves grown in increased CO_2 environments had lower nitrogen contents. The water content of the leaves is also favourably correlated with the performance of insect herbivores that nibble on leaves. As seen for both mustard and collard, increased CO_2 caused a decrease in the water content of leaves. Plants can use mechanical defence mechanisms, such as the presence of thick foliage or trichome-like structures on leaves. It has been noted that the effectiveness of herbivores is negatively correlated with the level of mechanical defence. With a special focus on factors like leaf toughness, leaf thickness, and specific leaf weight, numerous studies have found that increased CO_2 levels lead to an increase in mechanical defence. Hamilton et al. (2005) noted that cabbage white butterflies that fed on mustard or collard cultivated in an elevated CO_2 environment caused a higher percentage of leaf damage or consumption. On a variety of woody plants, leaf miners have shown comparable outcomes. The performance of insect herbivores is significantly harmed by high CO_2, according to Zvereva and Kozlov (2010). This might be because natural enemies like parasitoids cause increased mortality rates. Because their prey is easier to see, natural enemies are thought to be more successful in environments with higher CO_2. Increased leaf damage and the formation of frass, both of which are signals to natural enemies, follow higher consumption rates. In 2005, Hamilton et al. conducted research on soybean herbivory in various air environments. While increasing O_3 had little impact, elevated CO_2 increased soybean sensitivity to herbivory. At high CO_2, the amount of leaf area lost rose from 5% to more than 11%. At high CO_2, compensatory feeding was not noticed. When CO_2 levels were boosted and *Popillia japonica* populations rose, leaf sugars rose by 31%.

Effects of elevated temperature on insect pests

The effects of higher temperature on insect performance are primarily due to temperature's direct impact on insects, causing them to be more active in warmer conditions. Elevated temperature typically leads to increased consumption rates, decreased time to pupation, and potentially more generations per season. A temperature increase of 2^o C may result in one to five additional life cycles per season for insects. The effects of temperature on insect performance are mainly due to its direct impact on insects. As insects are exothermic, they tend to be more active in warmer conditions, leading to increased consumption rates and faster pupation. This may make them less noticeable to natural enemies and allow for more generations per season. It is estimated that a 2^o C temperature increase could result in one to five additional life cycles per season. While elevated temperatures enhance gypsy moth performance, they have a different effect on the survival rate.

The gender ratios of certain pest species, like thrips, might be affected by temperature changes, which could lead to changes in their reproduction rates. Insects that reside mostly in soil may be less affected by temperature changes because the soil acts as an insulator.

Warmer winter temperatures may lead to lower winter mortality of insects, which could increase insect populations (Harrington et al 2001). As latitude and altitude increase, insect species diversity per area tends to decrease. With rising temperatures, more insect species may attack more hosts in temperate climates.

Effect of changes in rainfall pattern on insect pests

With climate change, planting early and at the right time is less assured. Pigeon pea growing was delayed and significantly damaged in 2009 due to the monsoon's delayed arrival (Sharma, 2010). Changes in precipitation can have an impact on illnesses, parasites, and insect pest predators. The occurrence of fungi that cause fungal diseases in insects will rise as the environment changes. Since some insects are sensitive to precipitation, large rains can kill or remove them from crops. When deciding on onion thrips control options, this factor must be taken into account.

Impacts of climate change on insect pest scenario

The traits and habitats of many species, most notably insects, are being impacted by global warming brought by climate change. The timing of activities associated to insects, such emergence and arrival, is also being impacted. The spread of important crop pests and illnesses will result from these changes, which will affect human livelihoods. It is important to note how changing climate has an impact on population dynamics and insect pests.

1. **Expansion of geographic ranges:** Due to altering temperature and rainfall regimes brought on by climate change, species distribution, survival, and reproduction will be influenced in the future. A rise in temperature may cause insect pests to expand their range and move the locations of agriculture, leading to epidemics that may obliterate entire crop species. In contrast, warming in temperate areas may lead to a decline in the relative abundance of insect populations that are sensitive to temperature. In the future, it is anticipated that more frequent insect outbreaks may occur in temperate regions due to a rise in the frequency of droughts and global warming. The structure, variety, and efficiency of ecosystems in North India may alter as a result of the spread of migratory species like *Helicoverpa armigera* brought on by climate change.
2. **Increase in number of generations:** Given that temperature is the primary governing component for insects, an increase in global temperature that falls within a favourable range may help tropical and subtropical insects develop, reproduce, and survive at faster rates. Insects will be able to produce more generations every year as a result, which will ultimately result in more crop damage.
3. **Risk of introducing invasive alien species:** The Convention on Biological Diversity states that invasive alien species are the biggest danger to biodiversity loss globally and have a severe impact on forestry, agricultural, and aquatic ecosystems. Changes in phenological events brought on by global warming may exacerbate the ecological effects by introducing new pests, which could be a serious problem for crops susceptible to insects.
4. **Impact on pest population dynamics and outbreaks:** Insect-pest outbreaks have become more frequent and intense as a result of changes in climatic factors. Due to unpredictability changes in insect populations and their natural antagonists, this might disturb ecological balance. In 2002–2003, a sugarcane woolly aphid outbreak in Karnataka and Maharashtra resulted in 30% output losses. These widespread pest damages have driven up plant protection costs and decreased farmer income.
5. **Increased incidence of insect vectored plant diseases:** Due to the expansion of their range and the quick reproduction of the insect vectors involved, the phenomena of climate change has the potential to lead to an increase in the occurrence of insect-borne plant diseases. According to sources, early in the growing season, viral infections are more

common in potatoes because to increased temperatures, which might hasten the colonisation of virus-carrying aphids. In Northern Europe, potato viruses are a big threat.

Pest Management Adaptations to Changing Pest Scenario

1. Breeding climate-resilient varieties: It is crucial to produce new plant types with improved tolerance to abiotic and biotic stresses in order to lessen the consequences of environmental changes. It is critical to concentrate on producing varieties that can endure challenging climatic circumstances, pest and disease occurrences, especially those ideal for late planting, due to the risk of delayed and shortened growing seasons for specific crops in winter.

2. Alternation in sowing dates of crops: Crop sowing dates may change due to global climate change, which may also affect host-pest synchronisation. To find the ideal sowing dates for lowering pest pressure and raising production, it is required to evaluate the impacts of early, normal, and late sowing circumstances on host-plant interactions.

3. **Rescheduling of crop calendars:** Climate change may prevent some cultural practises from controlling crop pests. Calendars for planting crops must be changed as a result. Insect management tactics must be adjusted by growers to account for predicted changes in pest occurrence and crop losses brought on by climate change.

4. GIS based risk mapping of crop pests: Entomologists can use GIS to link insect-pest epidemics to geographical features. It works best when utilised in regional pest management initiatives. By foreseeing and charting anticipated changes in regional distribution, geographic information systems (GIS) allow researchers to examine how climate change will affect insect pests. This can be used to locate potential pest danger zones and agroecological hotspots.

5. Screening of pesticides with novel mode of actions

Even without insecticidal effects, neonicotinoid pesticide usage can increase plant vigour and stress tolerance. This indicates that finding other substances to manage crop pests is necessary. To combat pest issues under climate change regimes, additional research and strategies are required.

- Adapt temperature-tolerant natural enemy strains.
- Creation of models for weather and pest forecasting.
- Creating decision support and early warning systems.
- Knowledge of the effects of climate change.
- Adoption of mitigation and adaptation measures.
- Farmers' participation in research to improve flexibility

Conclusion

Pest damage in India differs in various agro-climatic regions due to varying abiotic factors. The livelihoods of rural farmers may be impacted by increasing production losses and an increase in insect pest occurrence as a result of climate change. The problem of climate change is difficult and multifaceted. In agricultural research, it is crucial to examine how crop plants, insect pests, and their natural enemies respond to abiotic stress. Planning pest management measures must take into account how crop productivity may be impacted by changes in insect-pest populations. It can be challenging to find a response to climate change due to species adaptations. Different species are impacted by changes in the thermal environment. Due of interconnections, it is challenging to predict how climate change may affect pest insects. Expect a rise in invading species, primary pests, and secondary pests. Farmers should use integrated pest management techniques. It's crucial to keep an eye on the spread of diseases and insects. To assess the economics and environmental impact of pest control, farmers should maintain data on pest and crop management. Potential adaptation options cited include improving IPM by putting more emphasis on biological control and changing cultural norms, utilising cutting-edge approaches like simulation modelling for pest predictions, and investigating alternative production systems.

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