AGRIBLOSSOM
A monthly peer reviewed e-magazine for Agriculture & allied Sciences
ISSN-2582-8258

Dynamism of IPM under changing climate

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Introduction

Climate change is the term used to describe a gradual increase in the average temperature of the earth atmosphere and its oceans, a change that is said to be changing the earth's climate forever. Climate change has become a household topic of discussion with more scientists getting involved in scientific research on the aspect while politicians trying to derive mileage from the paradigm. Climate change in the usage of the Intergovernmental Panel on Climate Change (IPCC) referred to "a change in the state of the climate that can be recognized by changes in the mean and/or the changeability of its properties that persist for an extensive period, typically for decades or longer". It refers to any change in climate after a while, whether due to natural changeability or as the outcome of human activity. Climate exerts powerful effects on the supply and abundance of the earth's insect species and we should expect climate warming to create changes for many insect populations and the ecosystems they live in. Warmer temperature generally lead to more fast development and survival in insects in mid to high latitudes, which can account for visible and definite shifts in a range of insect species more than the half century. Increased heat also advances the start of insect life cycles for the many species that use thermal cues to match the timing of life history actions with the changing seasons.

It is usually anticipated that a changing climate and more erratic weather patterns will make pest's attacks more unpredictable and their amplitude larger. With CO2 levels and temperatures increasing, precipitation becoming more changeable and non-native insect species moving into new array, changes in insect–plant interactions and IPM regimes will be substantive and less expected. Agro-ecosystem change may be that glasshouse pests could become more difficult in open pastures and field. Relaxed cold constraint could be one of the key drivers for exacerbating the increase of insect pests into new regions, and a longer growing season in current regions.

Cultural practices

Changing farming and adaptive management tactic will be required to reduce the impact that agricultural pests have on crops. This may contain, planting different plant varieties, variation of sowing date, mulching, raised beds, shelters, protecting crops from heavy rain, high temperature and flooding, preventing soil degradation and increasing the diversity of habitat on edges to encourage natural enemy numbers. At the farm level and the microclimate level, changing farming strategies is most significant. Crop rotation can aid in suppressing diseases, which are predicted to increase in prevalence under a changing climate. For example, planting oilseed, pulse and forage crops within a cereal cropping system disturb disease cycle.

Predators and Parasitoids

Biological control of insect-pests is one of the important factors of integrated pest management, safeguarding the ecosystem. Natural enemies of crop pest *viz.*, predators, parasitoids and pathogens are rapid density responsive in their action subjected to the action of abiotic components. Being tiny and fragile, natural enemies of the insect-pests are more sensitive to the climatic severe like heat, cold, wind and rains. Precipitation vary can also affect predator, parasite and pathogens of insect-pest resulting in a complex dynamic. With changing climate, incidence of entomopathogenic fungi might be favoured by extended humidity conditions and inflexibly be reduced by drier conditions. Parasitoid populations may also be disrupted by severe events and variable climate. There may also be spatial and temporal mismatches between pests and their natural enemies which will reduce the efficacy of biocontrol agents and predicting these impacts will be difficult without a thorough understanding of the tritrophic interactions among species.

Pesticides

Since the 1960s, there has been a 15-20 double increase in pesticide use. Additionally, as crop yield has enlarged, due to the use of high yielding varieties, soil and water management, fertilization and cultivation methods, there has been a raise in crop loss due to pest. Many new varieties of crops are more dependent on pesticides as they have lower tolerance to competitors and herbivores, as much of the inbuilt resilience is bred out. Pesticide applications are the primary method of managing pests in the industrialized world. The application of pesticides is associated with temperature at sites and site minimum temperature can provide as an alternate for pesticide application. For example, Ziska assessed pesticide applications on soybean along a 2100 km latitudinal gradient in the USA and found that soybean yield did not differ over the gradient, even as total pesticide application increased from

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4.3 kg ha^{-1} active ingredient in Minnesota (having a minimum daily temperature of -28.6 °C) to 6.5 kg ha^{-1}active ingredient in Louisiana (-5.1 °C minimum daily temperature). With a changing climate, herbicide use will increase in the other temperate regions, whereas there will be a greater increase in insecticide and fungicide utilize closer to the tropics. This is due to the fact that, in temperate regions, warming enhances growth and insect reproductive output, as well as survival.

Semio chemicals

The signaling chemicals which cause changes in the behavior of other living organisms play a vital role in IPM. The use of pheromones and allelochemicals is a key method that insect use to intellect their environment. Their use in monitoring, trapping, mating disruption, push pull strategies and biological controls makes them perfect for a range of IPM techniques. Temperature, humidity and air speed can have serious impact on the effectiveness of semio chemicals. The temperature used highly influenced pheromone rates, with half lives of the sex pheromone decreasing with an increase in temperature. Temperature has also been shown as the critical environmental variable influencing volatile release rates in moth sex pheromones, light brown apple moth pheromones. At high temperature, aphids have been exposed to be less responsive to the aphid alarm pheromone they release when under attack by insect predator and parasitoids resulting in the possible for greater predation.

SIT Technique

The sterile insect technique (SIT) is an important method used to control insects which release radiation induced sterile males into wild populations to reduce the number of offspring after mating with wild females. It is a key method used to control *Ceratitis capitata* (Tephritidae: Diptera) worldwide. One of the strains of *C. capitata* has a temperature sensitivity gene, *tsl*, which makes the homozygous female embryos susceptible to high temperature mortality (compared to males) after 24 hours of development. Females remain susceptible to temperature throughout their lifetime, but the impact of the *tsl* gene mutation or the effects of irradiation on released males in the field are currently unidentified. This advantage of lab reared sterile males could increase their usefulness as a pest management tool under a warming climate.

Agricultural impact assessment based on changing yield due to increased pressure from pest due to climate change is still in its infancy. However, it is clear that human induced climate change will have impact on all feature of IPM system, pest outbreak, pollinator synchrony with flowers, efficiency of crop protection technology, parasitoid and predator efficiency. This requires a greater understanding of pest population dynamics, thermal physiology, ecology, behaviour and hub IPM priorities. In addition to the strategies we require to decide the future research on breeding climate-resilient varieties, rescheduling of crop calendars, GIS based risk mapping of crop pests and screening of pesticides with novel mode of actions. Geographic information systems (GIS), global positioning systems (GPS) and remote sensing (RS) are allied technologies that together provide a means of gathering, integrating and analyzing spatial data.

Challenges ahead due to climate change

The future line of research for combating the pest problems under climate change regimes.

Breeding climate-resilient varieties

In order to minimize the impacts of climate and other environmental changes, it will be crucial to breed new varieties for improved resistance to abiotic and biotic stresses. Considering late onset and shorter duration of winter, there is chance of delaying and shortening the growing seasons for certain Rabi/ cold season crops. Hence, we should concentrate on breeding varieties suitable for late planting and those can sustain adverse climatic conditions and pest and disease incidences.

Rescheduling of crop calendars

Global temperature increases and altered rainfall patterns may result in shrinking of crop growing seasons with intense problems of early insect infestations. As such certain effective cultural practices like crop rotation and planting dates will be less or no effective in controlling crop pests with changed climate. Hence there is need to change the crop calendars according to the changing crop environment. The growers of the crops have to change insect management strategies in accordance with the projected changes in pest incidence and extent of crop losses in view of the changing climate.

GIS based risk mapping of crop pests

Geographic Information System (GIS) is an enabling technology for entomologists, which help in relating insect pest outbreaks to biographic and physiographic features of the landscape, hence can best be utilized in area wide pest management programmes. How climatic changes will affect development, incidence, and population dynamics of insect pests can be studied through GIS by predicting and mapping trends of potential changes in geographical distribution and delineation of agro-ecological hotspots and future areas of pest risk.

Screening of pesticides with novel mode of actions

It has been reported by some researchers that the application of neonicotinoid insecticides for controlling sucking pests induces salicylic acid associated plant defense responses which enhance plant

ISSN-2582-8258

vigour and abiotic stress tolerance, independent of their insecticidal action. This gives an insight into investigating role of insecticides in enhancing stress tolerance in plants. Such more compounds needs to be identified for use in future crop pest management.

Being a tropical country, India is more challenged with impacts of looming climate change. In India, pest damage varies in different agro-climatic regions across the country mainly due to differential impacts of abiotic factors such as temperature, humidity and rainfall. This entails the intensification of yield losses due to potential changes in crop diversity and increased incidence of insect-pests due to changing climate. It will have serious environmental and socio-economic impacts on rural farmers whose livelihoods depend directly on the agriculture and other climate sensitive sectors. Dealing with the climate change is really tedious task owing to its complexity, uncertainty, unpredictability and differential impacts over time and place. Understanding abiotic stress responses in crop plants, insect-pests and their natural enemies is an important and challenging topic ahead in agricultural research. Impacts of climate change on crop production mediated through changes in populations of serious insect-pests need to be given careful attention for planning and devising adaptation and mitigation strategies for future pest management programmes.

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