Applications of Simulation Modeling in Insect Pest Management

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Insect pest management can be described as a method to eliminate or reduce the population of undesirable insects. It deals with insect pests, its natural enemies and non-target species which are interrelated, subject to man-made production-intended interferences under varying weather conditions (Teng and Savary, 1992). Later, by the introduction of synthetic pesticides, the focus of pest management strategy shifted towards managing a particular insect pest with wide-spectrum insecticides, without considering other agro ecosystem components. This method was responsible for many problems related to pest management and the environment which resulted in the development of integrated pest management (IPM). The goal of IPM is to incorporate methodologies across all crop protection domains in a way that is consistent with crop production. In short, IPM can be called as applied ecology. Developing an IPM package demands detailed scrutiny of the system and in some cases, it may lead to the development of new management strategies by defining points of intervention (Pinnschmidt *et al.,* 1994).

With the advent of information technology, many tools were developed to resolve agricultural issues; crop growth simulation modelling is one among them. Simulation models are mechanistic models, which focus on quantitative knowledge of the underlying biological and chemical processes, crop physiological attributes, meteorological factors, pedological factors and incorporating the effects of pest, and their management factors on the crop growth and yield. These are knowledge-intensive tools and are universal, which can have limited as well as global applications (Chander *et al.,* 2007). Along with other system approach tools, they set up a shield for the incorporation of knowledge which can benefit several stakeholders (Aggarwal *et al.,* 2004). Crop growth simulation models like MACROS, CERES-RICE, CROPGRO, ORYZA, ALFAPRO2, SUCROS, WTGROS and INFOCROP were developed to look into the opportunities for increasing crop production. Advances in simulation modelling have also influenced integrated pest management (Chander *et al.,* 2007). Before 1960s, much of the research on pest management was done with empirical models. Some simulation models on population dynamics of single species were developed in 1970s and early 1980s. Later, population dynamics models comprising two trophic levels (pest species and natural enemies) were developed (Teng and Hofer, 1991). Later, decision support systems (DSS) started to advance with the incorporation of socio-economic and crop factors into pest models. A decision support tool in its simplest form is economic threshold level (ETL) and a computer system capable of integrating databases, algorithms and simulation model could be its advanced form (Teng *et al.,* 1998). Coupling of crop growth simulation models with pest effects at the physiological level has made great improvement in modelling crop – pest interactions, but a population dynamics part was missing in those coupled models. On the other hand, pest-crop models developed simultaneously, where crop and pest could influence one another dynamically (Pinnschmidt *et al.,* 1990). Further approaches have integrated the characteristics of the natural enemy component to pest–crop models. Research on pest management is essential to develop tools for enhancing pest management approaches. Such tools and decision models can be produced with the help of simulation models. In addition, simulation model development, analysis and evaluation are the common components of the system approach in pest management (Teng and Savary, 1992). Multifactor interactions in agro ecosystems can be analyzed with crop-pest models which relay on ecological processes and crop physiology and thus can have several other applications in pest management (Chander *et al.,* 2007). Some of the applications of simulation modelling in insect pest management are discussed below.

Determination of economic injury level (EIL)

Economic Injury Level (EIL) is defined as the minimum pest population density, which can lead to economic loss and Economic Threshold Level (ETL) is the level of pest population at which management measures needs to be taken, so as to prevent it from entering EIL. One would appreciate while learning how EIL is determined through simulation models. First of all, EIL is defined and then the ETL is set at a lower level than EIL, based on the pest multiplication rate. A desirable benefit-cost ratio could be attained by applying management measures at ETL. This means that, if we implement control measures at ETL, at least the cost of control is offset by the value of the crop spared from pest damage. It also leads to the judicious application of pesticides, which in turn reduces expenditure and pollution.

EIL can be determined with the use of crop-pest models. EIL is a dynamic entity that may vary with the growth stages of the plant or with geographical location or with the cost of control measures or with the market price of produce (Archer, 1994). The estimation of EIL by field experiments for various areas with different management measures and market conditions is a tedious job. However, EIL can be determined easily for many combinations of different variables, using a validated crop-pest model. For example, EILs of citrus rust mite (Allen, 1981), rice leaf folder (Satish *et al.,* 2007) and rice brown plant hopper (Sujithra et al., 2011) were determined with models. Similarly, simulation models can be used to determine EIL for multiple pests that infest the crop at the same time.

Rationalization of Pesticide Use

Coupled crop-pest models could be used for generating iso-loss curves. Iso-loss curves display different crop age and pest intensity combinations which result in the same amount of yield loss. For example, iso-loss curves were simulated in the case of rice stem borer (Reji *et al.,* 2008) and rice plant hoppers (Yadav and Chander, 2010). These curves can then be used in the pest monitoring programme. They also aid in the need-based implementation of management measures and prevent unwanted pesticide applications.

Risk analysis

Risk analysis is conducted to determine the probable damage by exotic pests if they are introduced into non-native regions. For example, in several countries, Hessian fly (*Mayetiola destructor)* is a very serious wheat pest but so far, it's not found in India. The entry of the pest into India by quarantine negligence may lead to havoc in the production of wheat. This can be measured using model simulation. It is not possible to intentionally carry the foreign pests under quarantine to other countries for testing its damage potential. In such cases, models can be very useful *i.e.* for assessing certain conditions where the exact fieldwork with pest might not be possible. SOYRUST, the soybean rust model predicts potential areas for soybean rust epidemics when operating with continental USA weather data (Yang et al., 1991). The losses incurred due to rust epidemics were calculated by linking model-produced disease estimates with the soybean crop model.

Pest Management Information System

Even though principles for developing information systems for pest management are well-founded, its adoption by farmers appears to be generally low. The farmers need an IPM system addressing multiple pests simultaneously because of the prevalence of several pests at a time in the field. There are only a few IPM programs that address different kinds of pests. Efforts have to be made to build a pest management programme which involves close participation of the farming community. Rather than using complex pest simulation models, the information system can include simpler simulation outputs such as EIL and iso-loss curves.

Ecological Pest Zoning

Pest zoning is a term especially applicable for the management of pests of large areas. The population dynamics model of pest can be used to find out the area of the same pest incidence potential in a region (Yuen and Teng, 1990). For example, it was possible to predict the regions of Haryana with a low, moderate, or high incidence of rice leaf folder (Chander *et al.,* 2006). Areas with the same potential for pest incidence need not be in continuity. The Pest Zonation protocol is as follows.

The pest population-weather model is developed based on long term pest incidence and weather data from a location. It then predicts the likelihood of pest outbreaks for the location. However, model results can be extrapolated to the whole region/state with the geographic information system (GIS) based on the historical weather data of different weather stations in the region/state. As a result, region/state is divided into zones of equal pest incidence potential based on the pest-weather relationship of a single location. Before the advent of GIS, such studies were not possible and pest-weather relations could be analyzed for individual locations only. Awareness of the occurrence of pests in different zones will aid in selecting suitable crop varieties (Chander *et al.,* 2007). This will also assist extension personnel in choosing suitable management solutions for various areas. Identification of pest hot spots will also be possible.

Climate Change Impacts on Crops and Insect Pests

It has been reported that global temperature and CO_2 are increasing since many decades.

This is likely to continue, which will affect the earth's climate. The increase in temperature and CO_2 will both influence crop growth and pests (Chander *et al.,* 2007). The effect of anticipated climate change on crops over successive decades can be simulated using crop-pest simulation models. Likewise, the effect of climate change on pests can be measured with the population dynamics model. The ultimate impact on agricultural production will rely on crop-pest interaction.

Pest forecasting

Pest populations can be anticipated using population dynamics models. In mathematical equations, these models represent various phases of pest growth such as egg, larval, pupal, and adult development. The size of the pest population in various stages can be predicted by running these models with weather data of a region. Hence, these models can play an important role in timely pest management.

Conclusion

Crop growth simulation models have contributed in improving the efficiency of field research by its wide range of applications in pest management. Earlier the applications of crop growth simulation models were limited, but later with the availability of data on the various attributes these models have got many applications. These simulation models have been applied in various areas of research *viz*., to study the impact of climate change on crop yield and pest occurrence, transgenic environmental impacts, pest forecasting, and sanitary and phytosanitary pest risk analysis. Even though the decision support system in pest management has developed from a simple decision tool to an optimization software with several criteria, for the convenience of users, a decision support system based on the simulation model needs to be developed.

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