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Review Article

A REVIEW OF THE MODELLING CLIMATE CHANGE IMPACTS ON INSECT PEST POPULATION DYNAMICS

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Abstract- A warming climate has the potential to significantly modify the actual distribution of insect pests in agroecosystem. Insect pest models allow the estimation of the potential effects of a warming climate based on their physiological responses to specific weather factors. The global climate changes have notable impacts on agriculture as well as crop pests. Crop plants and their associated pests both are directly and indirectly influenced by climatic change. Climate change affects insect, mites, nematodes, other invertebrates, vertebrates and also microbial pests and the damage they cause is directly influenced by their reproduction, development, survival, spread, population dynamics or altering host defences and susceptibility. Indirectly, climate change impacts the relationships between pests, their environment and other species such as natural enemies, competitors, vectors and mutualists. Mechanistic models of the impacts of climate change on insects can be seen as very specific hypotheses about the connections between microclimate, eco-physiology and vital rates. These models must adequately capture stage-specific responses, carry-over effects between successive stages, and the evolutionary potential of the functional traits involved in complex insect life-cycles.

Keywords- Model, Climate change, Insect-pest, Population dynamics.

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Introduction

Major shifts in temperature and changes in the seasonal pattern of rainfall distribution are currently affecting most of the world. Climatic projections suggest that these trends will continue in the coming decades, affecting both mean and extreme values of these variables. In the latest report of the IPCC, mean global temperature is estimated to increase between 1.8 and 4.0 ◦C (with a likely range of 1.1–6.4◦C), by the end of the present century, depending on the greenhouse gas emission scenario Easterling *et al*. [1]. The problems of agriculture in many tropical countries are gradually becoming more intense due to increasing food demand led by population growth, stagnation in farm productivity, mounting yield losses due to multiple pests, increasing vulnerability to global environmental changes. Info Crop, a generic crop model, simulates the effects of weather, soils, agronomic management (planting, nitrogen, residues and irrigation) and major pests on crop growth, Aggarwal *et al*.[2]. Climate change may impact patterns of plant diseases and arthropod development in more complex ways than expected. In fact, whereas both crops and crop pathogens and pests are affected by climatic variables, they might be influenced by different combinations of driving factors, and they might respond to their change at different rates, Caffarra *et al*. [3]. Model simulations provided realistic trajectories of population dynamics of insect pests that can be important tools for the development of sustainable pest management. Giliolia *et al*. [4]. Info Crop-rice lacked an insect population dynamics component, undertaken to develop a BPH population simulation model and link it with Info Crop-rice to facilitate climate-change-impact assessment on pest population as well as on crop-pest interactions, Sujithra and Chander [5]. Crop growth simulation models based on crop ecological and physiological processes and coupled with pest damage mechanism are useful tools for analysis the interactions of pests with other biophysical components of agroecosystem. The impact of future climate change on crop production has been widely studied by using crop models and climate change scenarios, Hui *et al*. [6].

Various types of models

Model: A model is a simplified representation of a system.
Qualitative or quantitative

Quantitative

Empirical models: Regression models (descriptive models)
Simulation models: Mechanistic or explanatory models.

Simulation models

Static mechanistic models: relationship between variables does not involve time
e.g. relation between respiration and growth or
No. of eggs = fecundity* sex ratio* females

Dynamic mechanistic models: account for changes with time
Static models constitute a part of Dynamic model

Dynamic

Dynamic discrete mechanistic model: account for change in steps

Dynamic continuous mechanistic model: account for gradual changes

Agricultural Systems: Dynamic Continuous Systems

Models: Dynamic Continuous Mechanistic Models
Info Crop is a generic crop model developed to meet these specific requirements. It is designed to simulate the effects of weather, soils, agronomic management (including planting, nitrogen, residues and irrigation), and major pests on crop yield and its associated environmental impacts, Aggarwal *et al*.[2].

By using appropriate switches, (damage mechanism) different combinations of selected critical processes can be simulated, Aggarwal *et al*.[7].The mechanistic assessment of crop losses is a three-step approach taking into consideration the pest incidence, pest damage mechanism, and the crop yield. InInfoCrop, pest population dynamics is not simulated at present; therefore, pest incidence has to be provided as an input. Different categories of damage mechanisms encompass reduction in germination and plant stand, competition for resources (radiation and nutrients), reduction in assimilation rate, assimilate consumption, tissue consumption and hampering of water and nutrient uptake. **Germination reducers**: Pests such as mole cricket and seed maggots damage seeds in the soil before germination. In InfoCrop, their effect is simulated by reducing initial leaf and root weight at seedling emergence in proportion to the reduction in germination due to pest. **Stand reducers:** These are insects or diseases that kill whole plant or part of it, for example, stem borer, cutworms, termites, damping-off and wilts. The severity of loss due to these pests depends upon number and distribution of lost plants, compensation ability of remaining plants and development stage of the crop. **Light stealers:** Light stealers are those pests, which intercept photosynthetically active radiation before it can be utilized by plants for photosynthesis. Diseases such as rust, blights, mildew, and sooty mould developing on honeydew excreted by sucking pests constitute this category of pests. Light interception by necrotic lesions on leaves of crop plant may also interfere with photosynthesis. **Assimilation rate reducers:** Many pathogens and insects affect the photosynthetic capacity of green tissues of plants by affecting structure and function of chloroplasts. Diseases such as powdery mildew, blight, rust and virus diseases belong to this category. **Assimilate sappers:** Sucking pests such as aphids, plant hoppers, whiteflies, mites, thrips and bugs suck assimilates from plant, and as a result less carbohydrates remain available for plant growth. Reducing the rate of available assimilates for plant growth simulated their effect on plants. These pests may suck sap from all plant parts or any of the plant parts. **Tissue consumers:** These pests feed on different plant parts such as roots, leaves, stems and storage organs. Leaf consumers such as defoliating beetles, grasshoppers, leaf folders, leaf miners, node borers, grain feeders and foliar diseases such as leaf blights, blast and sheath blight reduce the capacity of the crop to capture radiation for photosynthesis and are most common.

Process of formulating models and analyzing systems through them-
Define goals-Purpose of modeling should be clearly defined. All problems are not amenable to modeling.

Define system and its boundaries-Crop growth and productivity affected by climatic, soil, hydrologic, biotic, agronomic and socio-economic factors

Define key variables in the system-State variables describe the state or condition of the system. Biomass, leaf area, amount of nitrogen, water in the soil etc. Number of eggs, larvae, pupae and adults.

Calibration-Adaptation of crop growth simulation model to a particular experimental condition.

Validation-Model validated for various pest infestation treatments. Pest infestation levels observed in the field are input in the model. If model output is comparable to field output then pest damage mechanisms are taken as validated. Validated model then can be used for various applications in pest management.

Applications of simulation models
Establishment of economic injury levels
Rationalization of pesticide use
Pest management information system
Predictive pest zoning
Agro-ecological zoning
Risk analysis
Analysis of Impact of Climate change

Analysis of Impact of Climate change
Effect of climate change on pest population can be studied through dynamics model
Effect of climate change on crops can be analyzed by crop simulation models
Ultimate effect of climate change on production will be assessed by linking pest population and crop growth simulation models

A modelling framework for pest population dynamics
Mechanistic models for population dynamics based on physiological responses at individual level to environmental driving variables have been proposed since the 1970s These models have been defined as physiologically based demo-graphic models (PBDMs) and offer several advantages for developing sustainable crop production systems, For example: they account for the non-linear relationships between environ-mental forcing variables (e.g., temperature) and the biological processes enabling the population dynamics to be described realistically.
The stochastic demographic model is based on a system of partial differential equations that allows obtaining the temporal dynamics of the stage-structured population and their distribution on physiological age within each stage, Giliolia *et al*.[4].

The bio-demographic functions
The PBDMs approach requires parameterisation of basic bio-demographic rate functions, for development, fecundity and mortality. These functions are common to poikilotherm organisms across many different taxa, with the physiological responses to environmental forcing variables. Temperature is considered the most important driving variable in poikilotherm and is introduced in the dynamic models as an independent variable in the rate functions.

Development rate function
The development rate depends on environmental temperature. We use the development rate Lactin function, though other functional forms for the development rate function, similar to the Lactin function.

Fecundity rate function
Egg production is dependent on the physiological age of the adult, the phenological stage of the plant and the temperature.

Mortality rate function
The mortality rate function is composed of intrinsic temperature-dependent (abiotic) mortality and a stage- and generation-dependent extrinsic mortality likely related to external natural control factors.

Mechanistic models for predicting insect responses to climate change
Mechanistic models of the impacts of climate change on insects can be seen as very specific hypotheses about the connections between microclimate, ecophysiology and vital rates. These models must adequately capture stage-specific responses, carry-over effects between successive stages, and the evolutionary potential of the functional traits involved in complex insect life-cycles. Mechanistic models can be particularly useful for prediction under novel circumstances. Using the observed trajectory of a grasshopper in flight, extrapolation by a correlative model makes an unrealistic prediction of the grasshopper's future position. Building the laws of motion into a mechanistic model, such as gravity and air resistance, improves the prediction and applies anywhere these physical rules operate, for example, on a novel planet. Likewise,

building in known biological processes into mechanistic models will improve predictions of species' responses to novel climatic circumstances. Maino *et al*.[8].

Simulation of rice brown planthopper, *Nilaparvata lugens* populations, Sujithra and Chander [5] studied impact of climate change on BPH population, crop yield and crop-pest interactions was studied through coupled InfoCrop-rice model by using climate change projections for Indian subcontinent based on CCSR/NIES model predictions, Lal *et al*. [9].

Coupled BPH- InfoCrop Rice model could be used to simulate climate-change impact both on pest population as well as crop–pest interactions. Model simulation depicted that, due to temperature rise, BPH population would decline by 3.5 and 9.3–14%by 2020 and 2050, respectively, at New Delhi. On the other hand, temperature rise would not affect BPH population by 2020 at Aduthurai during the winter but population would decline by 2.1–3.5 % by 2050. The decline in BPH population could be ascribed to reduced fecundity and survival under changed climate. Owing to reduction in population with temperature rise, BPH-induced yield loss also showed a declining trend. However, the study considered the effect of temperature rise only on the BPH population without accounting for change in feeding rate and adaptive capacity of the pest, which needs to be addressed to ensure more precise simulation of climate change impact on crop-pest interactions.

Simulation of climate change impact on rice pink borer *Sesamia inferens*, Krishnan and Chander [10] Validation of pink stem borer population simulation model-The population simulation model of the PSB was validated using field experiment data that was acquired during the rainy season in 2004. Impact of climatic change on the PSB population and crop-pest interactions studied through the coupled InfoCrop-rice model.

Concomitant to a decline in the PSB population, pest-induced yield losses in rice depicted a declining trend with increased temperature in our study. However, rice productivity also declined under climatic change even without pest stress. The coupled model could predict probable changes in rice yield and yield losses caused by the PSB under different climatic change scenarios. The PSB population simulation model coupled to InfoCrop rice model thus facilitated assessment of climatic change climatic on the pest dynamics as well as crop-pest interactions in rice.

Conclusion

A model can be used to investigate a wide verity of "what if" questions about real-world system. Pest coupled - InfoCrop model could be used to simulate climate-change impact both on pest population dynamics as well as crop–pest interactions. The coupled InfoCrop-rice model can easily be adapted to diverse agro-ecologies and used for location-specific applications related to climatic change impacts and pest forewarning. Known biological processes into mechanistic models can be improve predictions of species' responses to novel climatic circumstances.

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Abbreviations:

IPCC- Intergovernmental Panel on Climate Change

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Conflict of Interest: None declared

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