

Development and Validation of a Simulation Model of Pink Bollworm Population Dynamics

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ABSTRACT

A process-oriented simulation model of pink bollworm population dynamics in commercial cotton has been developed. The model, written in FORTRAN, is driven primarily by temperature and crop phenology. In addition to key ecological parameters, the model incorporates the impact of multiple insecticide applications. The model is presently being validated and modified for use as an on-line management tool.

INTRODUCTION

Simulation modeling with high-speed computers is a powerful tool that can be used to study complex systems, including those we experience in agricultural production. Because of the complexity inherent to the pink bollworm (PBW)-cotton interaction, I have developed a simulation model to study the system in detail. The model has proven to be useful for both research and management applications. In this report, I briefly describe the development of the model, preliminary validation work, and potential applications.

MODEL STRUCTURE AND PARAMETERS

Model development consisted of identifying all salient PBW biological processes and quantifying these relationships, usually as a function of temperature, age or nutrition (e.g., boll age). Mathematical formulae describing each process were then incorporated into a simulation model structure written in FORTRAN.

The model converts calendar time to a degree-day (DD) time scale to neutralize the effects of fluctuating temperatures on PBW development, survival and fecundity. DDs are calculated in 1/2-day time-steps using the sine wave algorithm of Allen (1976) and average lower and upper temperature thresholds of 51.6° and 90.5°F, respectively (Hutchison et al. 1986). Each day of the simulation, DDs are accumulated, individuals in each age-class (e.g., eggs, 1st-instar larvae) are aged, individuals that die are subtracted, those that have accumulated enough DDs are transferred to the next age-class, and depending on moth age, a new cohort of eggs are laid.

A time-varying distributed delay (Manetsch 1976) approach was used to model the development and mortality of individuals in each age-class. This method provides a convenient way to incorporate the variability associated with insect developmental rates. Laboratory estimates of temperature-dependent egg, larval and pupal developmental times (Hutchison et al. 1986) were verified with developmental times observed by McLaughlin (1972) under field conditions. Age- and time-specific mortality for all immature stages was taken from Brazzel and Martin (1955), McLaughlin (1972) and Hutchison et al. (1988a). The age- and temperature-specific oviposition relationship was developed using data from Graham et al. (1967) and McLaughlin (1972). The influence of larval nutrition on PBW oviposition was taken from Gutierrez et al. (1977). Percentages (35-50%) of eggs actually laid on bolls during July-August was estimated from the data of Brazzel and Martin (1957). The impact of insecticide applications, as measured by delayed PBW oviposition rates, was taken from Hutchison et al. (1988b).

MODEL INPUT AND INITIALIZATION

The model is initialized with either daily or twice-weekly moth trap catches (e.g., 1/10 of avg. no. caught in Delta traps) during the emergence period, primarily May 1 to June 15. Once bolls are present, usually June 15 for cotton planted in late March, initialization is terminated, and the model then simulates subsequent population growth during the boll-producing time of the year (mid-June through mid-September). Other information needed for the simulation include: daily max-min canopy (preferred) or ambient temperatures, planting date, date of first boll (avg. of one/plant), dates of insecticide applications, type(s) of material used, and stop-date.

MODEL VALIDATION

Fig. 1 illustrates the model's behavior for a 1986 field that received 10 insecticide applications (4-Pydrin, 3-Azodrin and 4-Ambush; pyrethroids applied with or without chlordimeform). As shown, the model provides a good representation of the observed data, simulating the timing and magnitude of population peaks. Similar results have also been obtained with one other insecticide-treated field (6 applications) and an untreated field.

FUTURE STUDIES

Additional field data are presently being used to validate the model over a more extensive variety of field conditions and insecticide treatment regimes. A larval density/damage/yield and economics routine is also being added to the model. Long-term plans include coupling the pink bollworm model with a plant model and incorporating these models into an interactive expert system. The expert system will be designed in such a way as to maximize its potential use as an on-line management tool.

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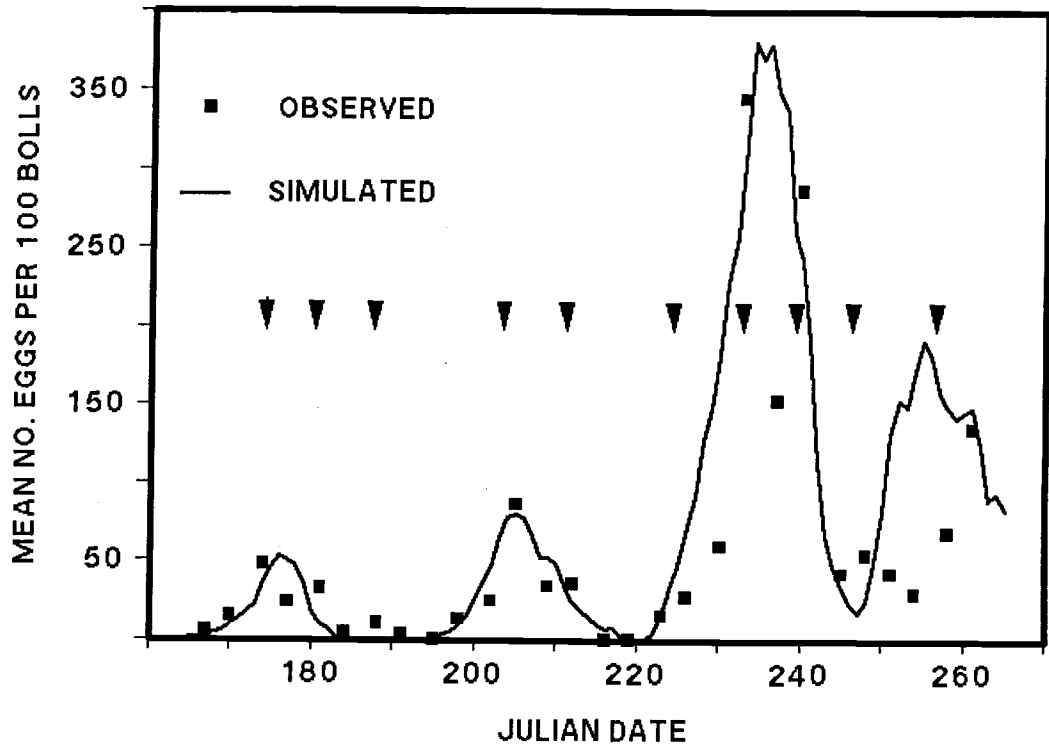


Fig. 1. Simulated and observed pink bollworm egg populations in a field treated with 10 insecticide applications; arrows indicate treatment dates (Field K3; 1986; Palo Verde Valley, CA).