RISK ASSESSMENT MODELS TO PREDICT DYNAMICS OF PINK BOLLWORM IN THE SOUTHEASTERN US

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Abstract

Pink bollworm (PBW), *Pectinophora gossypiella* (Saunders) remains a significant economic pest of cotton in the southwestern US. This project aims to determine the extent that PBW can invade and establish economic infestations in cotton producing areas within the southeastern US. In the first phase of the risk assessment, we identify regions where survival and reproduction of PBW are most likely. Three analyses based on the climate matching software CLIMEX indicate that the probability of establishment is >50% in portions of almost every cotton producing state in the southeastern US. Cold temperatures reduce the chance of establishment in more northern states, and excessive soil moisture limits chances in parts of the Southeast. In the second phase of the risk assessment, we determine the severity of infestations in high risk areas with the process-oriented computer simulation PBWSIM. PBWSIM models the dynamics of pink bollworm populations in response to temperature, crop phenology, and insecticide applications. Analyses based on weather data for the southeastern US are in progress.

Introduction

Pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), was first detected in the US in 1917 and subsequently spread from Texas to California. Early in the course of its invasion, establishment of PBW in all cotton producing regions of the US was taken for granted (Curl, 1938). PBW remains a significant economic pest of cotton in the southwestern US (Hutchison, 1999). However, PBW has been unable to establish economically damaging populations in midsouthern or southeastern regions of the country despite infrequent outbreaks in Florida, Georgia, Louisiana, and Missouri. Eradication efforts from the 1930's-1950's may have prevented establishment, and on-going monitoring and spot-eradication programs may keep PBW out of these regions. However, prevention programs can be costly, and may be unnecessary, particularly if climatic conditions preclude the possibility of establishment. We propose a two-phase approach to assess the probability that PBW will establish in southeastern US cotton. First, we coarsely identify geographic regions where temperature and moisture would support the reproduction and survival of PBW. Second, we predict the dynamics of PBW in high-risk areas with a detailed process oriented computer simulation (PBWSIM; Hutchison, 1988).

Methods

Climate matching software CLIMEX was used in three ways to assess the potential suitability of the climate in the southern US for PBW establishment (Venette and Hutchison, 1999). Two methods were based upon known or assumed PBW population responses to hot, cold, wet and dry conditions. With this information and historical climate data for 423 locations in North America, Climex generated a number of indices describing the potential for population growth or decline (Sutherst and Maywald, 1985). Logistic regression analyses were applied to Climex output to determine which indices best predicted establishment. Resulting models quantified the probability of establishment. In a separate set of analyses, we also compared the similarity of climates where PBW is known to occur in the US to other regions of the country. All results are geographically referenced in the geographic information system, ArcView 3.0 (ESRI, Redlands, CA).

The dynamics of PBW in high-risk areas (i.e. where the probability of establishment is >50%) will be predicted with PBWSIM. PBWSIM is a computer model that forecasts population dynamics of PBW on cotton. The model describes development, survivorship, and fecundity as a function of temperature (i.e. degree days) and crop stage. Degree days are determined in ½-day time steps using the sine wave approach. The model also accounts for the impact of insecticides via direct adult mortality and indirectly via disruption of pheromone communication, delayed mating and reduced fecundity.

Results and Discussion

Three independent analyses based upon logistic regression of Climex output indicate that the probability of establishment is >50% in portions of Missouri, Arkansas, Louisiana, Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, Virginia, and Tennessee (Fig. 1). All logistic regression models correctly classified 89-93% of the locations where pink bollworm was known to be present in the southwestern US or absent outside the US cotton belt. The models incorrectly classified 13-18% of the cases where successful establishment, and 5-8% of the cases where failed establishment, were predicted. In more northern states, cold winter temperatures (<6.5°C) cause direct mortality to PBW, or cool spring temperatures (<10°C) provide insufficient degree days for PBW to complete development. Temporary moisture saturation of soils in parts of the southeastern US may reduce, but not eliminate, the chances of establishment.

The effects of extreme cold and/or wet conditions on PBW survivorship are not well described in the literature. The limited data that are available may not reflect any

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selection/adaptation that may have occurred since PBW arrived in the US (Watson *et al.*, 1974). Moreover, experimental conditions often resemble the climate of the southwestern US, where PBW is established. Our risk assessment highlights the need for controlled studies of PBW survivorship under environmental conditions common to the southeastern US.

PBWSIM accurately describes the development of PBW from eggs to adults under constant, controlled temperatures (Fig 2). Approximately 550 degree-days (above a threshold of 12°C) are required for PBW to mature. Mortality in the field is greatest for eggs and first-instar larvae. From an initial cohort of 100 eggs, only 5 will survive to adulthood (Fig. 3). Using temperature data from southern California to drive the model, PBWSIM provided biologically reasonable results (Fig 4). The model predicted four generations. Prior to the formation of squares and bolls, the number of larvae was undetectable. The number of larvae steadily increased with each generation after July 1 (JD 182). In the future, diapause algorithms will be incorporated into the model to expand its utility from a single growing season to multiple years.

PBWSIM will allow us to explore several scenarios relative to the potential invasion of PBW into the southeastern US. We can use the model to examine the effect of initial population size, population stage, date of arrival, and single vs. multiple introductions on the ultimate fate and impact of a newly introduced PBW population.

Summary

Environmental conditions in Missouri, Arkansas, Louisiana, Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, Virginia, and Tennessee are likely support the reproduction and survival of PBW. More northern states are too cold for the pest to establish. Localized areas within the southeast may be too wet to allow PBW populations to persist. A simulation model has been developed (PBWSIM; Hutchison, 1988) and is currently being refined to predict changes in the size of PBW populations. The model will be used to predict the severity of infestations in high-risk areas within the southeastern US.

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Figure 1. Potential distribution of pink bollworm in North America. Shaded areas indicate where the probability of establishment is >50%.

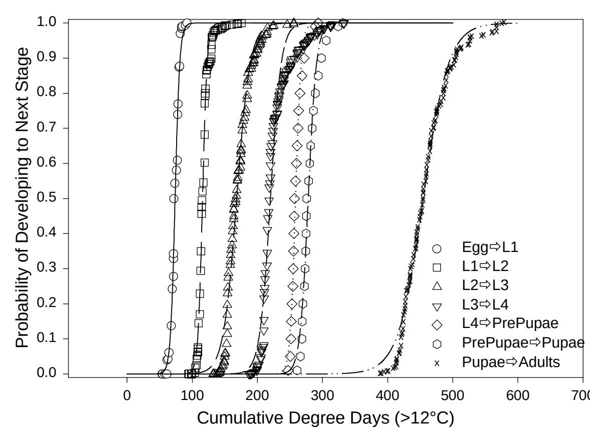

Figure 2. Development of pink bollworm population as a function of degree days. Symbols equal observed development. Lines equal predicted development in PBWSIM.

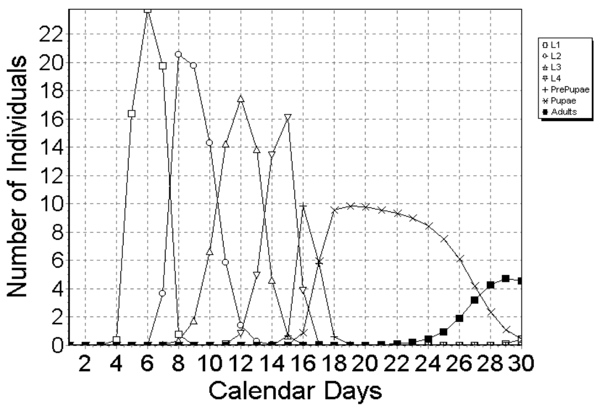

Figure 3. Predicted development and mortality within a cohort of PBW starting with 100 eggs at a constant 29°C (from PBWSIM).

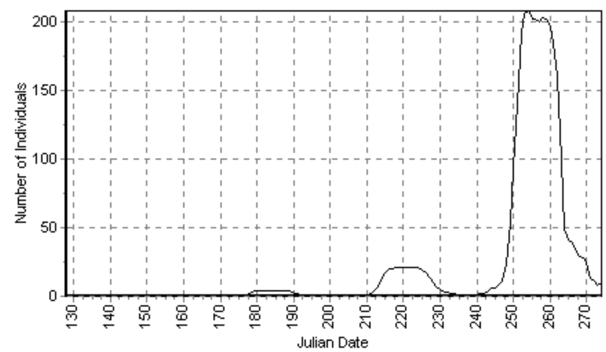

Figure 4. Simulated PBW larval dynamics from PBWSIM. Temperature data from southern California drive the model. The model assumes a single introduction of 100 moths one month prior to first boll (June 8, JD 159). Larvae from first generation on vegetative cotton is not detectable.