ESTABLISHMENT OF PINK BOLLWORM IN SOUTHEASTERN US COTTON: LABORATORY EXPERIMENTS AND MODEL VALIDATION

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Abstract

Although the pink bollworm, *Pectinophora gossypiella* (Saunders), remains a significant pest of cotton in the southwestern United States, the pest has not yet become established in southeastern US cotton. The objectives of this study were to determine how low temperatures and high soil moisture common to the southeastern US might affect mortality of diapausing and nondiapausing larvae of pink bollworm. In the laboratory at constant temperatures, moisture (0%), and darkness, nondiapausing prepupal larvae died more quickly as temperatures were lowered from 22 to 10 to 5˚C. At 5˚C, 90% of the population was dead after 12 days. Under similar experimental conditions, prepupal larvae reared under diapause inducing conditions (20˚C, 10L:14D), but showing no developmental evidence of diapause, also died more quickly at lower temperatures. In this case, 26 days at 5˚C were required to achieve 90% mortality. For diapausing, prepupal larvae collected from the field, mortality was greater at 5˚C than at 20, 15, or 10˚C, but larvae could withstand 5˚C for 60 d before 90% of the population died. In response to moisture, as soils at 10˚C became saturated (>165% gravimetric soil moisture), most larvae (≈60%) died within the first 10 d of the experiment. Diapausing individuals are more resilient to cold temperatures than nondiapausing individuals, but winter temperatures in the southeastern US are not sufficiently cold to completely preclude establishment of pink bollworm. Only northern Missouri has maximum air temperatures ≤5˚C for enough time to significantly affect numbers of diapausing larvae.

Introduction

Pectinophora gossypiella (Saunders), pink bollworm, is a significant pest of cotton worldwide. Where pink bollworm is established, larvae may reduce lint yields by as much as 60% (Fry et al. 1978). However, damage in commercial fields is typically limited to ≤10% due to management activities (Hutchison 1999). To limit the spread of pink bollworm in the United States, federal quarantine prohibits the transport of cotton plants (and other hosts), cottonseed, cotton refuse, and harvesting equipment from infested states (Arizona, New Mexico, Oklahoma, Texas, and southern California) to other cotton producing regions of the country (USDA 1997).

Regulatory action may prevent the establishment of pink bollworm in midsouthern and southeastern US cotton. However, regulatory action may be unnecessary if climate in the eastern half of the Cotton Belt is not adequate to sustain reproductive populations of the pest.

A recent risk assessment of the potential establishment of pink bollworm in the southeastern US suggests that climate is a critical determinant of the geographic range of this pest (Venette and Hutchison 1999). Cold winters increasing overall mortality or cool springs providing inadequate degree-days for the pest to complete physiological development in the Northern US are likely to confine populations to more southern climes. Excessive moisture may also increase population mortality in the eastern half of the United States. However, most of the Cotton Belt is likely to provide suitable habitat for local reproduction and population maintenance of pink bollworm (Venette and Hutchison 1999).

The risk assessment by Venette and Hutchison (1999) emphasized the importance of measuring survival of *P. gossypiella* under temperature and moisture conditions common to southeastern United States cotton. Published reports do not indicate a consistent impact of temperature or moisture on the demography of *P. gossypiella*, prompting Venette and Hutchison (1999) to conclude that this basic information remains a significant knowledge gap. The objective of the current study is to investigate the effects of cold temperatures and wet soils on the survivorship of late-instar larvae. We then use this information to refine estimates of where establishment of *P. gossypiella* might be precluded in the southeastern United States.

Materials and Methods

Four experiments were conducted to examine the effects of low temperatures and wet soils on mortality of pink bollworm larvae over time. Experiments 1 and 2 were conducted with pink bollworm larvae obtained from a colony maintained at the USDA-ARS Laboratory in Phoenix, AZ. For experiment 1, rearing containers with developing larvae were held at ≈25°C (14L:10D) until prepupal larvae emerged (i.e., "cut out"). Prior to experiment 2, we attempted to induce diapause by exposing larvae (starting at neonate stage) to 10L:14D at 20˚C (as per Gutierrez et al. 1981). Further evaluation revealed that diapause was not induced in these larvae. These non-diapausing, prepupal larvae were used as described below.

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Experiments 3 and 4 were conducted with diapausing larvae from cotton bolls collected in Blythe, CA in late September 1998. Diapause was verified by exposing 200 putative diapause larvae under long day conditions (16L:8D) at 27˚C. Approximately 5% pupation occurred by 60 days under these conditions.

Experiments 1 and 2

Fifty larvae were placed in a waxed paper cup (6 cm x 9.5 cm dia.) filled about half full with small, dry styrofoam beads (ca. 3mm dia.). The styrofoam provided a medium in which the larvae could readily burrow and spin hibernacula in preparation for pupation. For experiment 1, a total of 16 cups was prepared for each of 3 holding temperatures (5, 10, and 22± 0.5˚C at 0L:24D). After 1 d and at weekly intervals thereafter, two cups (i.e., replicates) were taken from each experimental temperature and destructively sampled for live and dead larvae, pupae and adults. Experiment 2 was conducted similarly except that larvae were held at 4 temperatures (5, 10, 15 and 20±0.5˚C at 0L:24D) with 4 replicates of each treatment.

Experiment 3

Fifty larvae were placed in waxed paper cups filled about half full with a potting soil mix. The soil mix was a blend of commercial potting soil (Perma-Gro, Tempe, AZ), sand, peat moss and perlite with an overall composition of ≈32% organic matter. The soil mix was sterilized by autoclave and dried to 0% moisture prior to use. Larvae were place on the soil surface and allowed to burrow for 24 h at room temperature (≈25°C) before being placed at four experimental temperatures (5, 10, 15 and 20±0.5˚C at 0L:24D). A total of 18 cups was prepared for each temperature. Three cups (i.e., replicates) per temperature were destructively sampled about every 10 days. An additional treatment consisting of dry styrofoam beads rather than soil was prepared and placed at 10˚C.

Experiment 4

As before, 50 larvae were placed in waxed paper cups filled half full with the sterilized soil mix. Larvae were place on the soil surface and allowed to burrow for 24 h at room temperature (≈25˚C) before adding de-ionized water to achieve soil moisture levels of 0, 50, 100, 150, and 200% moisture (by weight). Previous soil analysis (Soil Characterization Laboratory, Univ. Minn., St Paul, MN) indicated that the soil mix became saturated at ≈195% moisture by weight. All cups were held at 10˚C (0L:24D). Three cups per moisture level were destructively sampled about every 10 days. At the time of sampling the remaining cups were weighed and adjusted for any moisture loss due to evaporation.

Data Analysis

Probit analysis was used to estimate the amount of time (±95% fiducial limits) necessary to achieve 90% percent mortality (i.e. LT90) in a specific treatment. Each experiment was analyzed separately. We then used the climatological software, ClimProb v. 3.1 (High Plains Climate Center, University of Nebraska, Lincoln), to determine the median number of days per year with a maximum air temperature <5˚C. Analyses were conducted for a total of 188 locations in Missouri, Arkansas, Tennessee, Louisiana, Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, and Virginia.

Results and Discussion

In Experiment 1, mortality of nondiapausing larvae at 22˚C was independent of time over the course of the experiment (Table 1). Despite minor differences in initial mortality, larvae died most quickly at 5˚C and more quickly at 10˚C than at 22˚C (Table 1). LT_{90}s were lower at cooler temperatures (Table 2).

In Experiment 2, mortality at 20˚C was again not related to time (Table 1). Larvae generally died more quickly as temperatures were lowered. The LT_{90} at 5˚ was substantially less than at any other temperature (Table 2). The LT_{90} for 10 and 15˚C were less than the LT_{90} for 20˚C but were not different from one another (Table 2).

For Experiment 3, mortality of diapausing larvae at 20˚C increased with time (Table 1). Larvae died at the same rate at 20˚, 15˚, and 10˚C. For diapausing larvae, only the LT_{90} for 5˚C was different from any other treatment. (Table 2).

The median number of days per year with a maximum air temperature <5˚C was greatest in northern Missouri and declined with distance to the south (Fig. 1`). We selected the LT_{90} for diapausing larvae, as a critical time interval. In all states examined except Missouri, this critical time period was never exceeded.

Finally, in Experiment 4 mortality of diapausing larvae was greater as soil moisture increased (Table 3). The predicted amount of time required for 90% mortality declined as soil moisture increased (Table 4).

Our studies explicitly compare the likelihood that non-diapausing, pre-diapausing, or diapausing larvae could withstand adverse conditions in the Southeast until establishment is possible. Our results suggest that the introduction of diapausing larvae into the southeastern United States would increase the risk of pink bollworm becoming established more than the introduction of nondiapausing larvae. In southeastern United States cotton, coldspells are

neither sufficiently severe nor long to ensure >90% mortality of diapausing larvae.

The midsouthern and southeastern region of the US is cooler and more rainy than the southwestern US where pink bollworm is a perennial pest (Venette and Hutchison 1999). However, these climatic differences are not sufficient to eliminate the possibility of permanent establishment in the eastern half of the US Cotton Belt.

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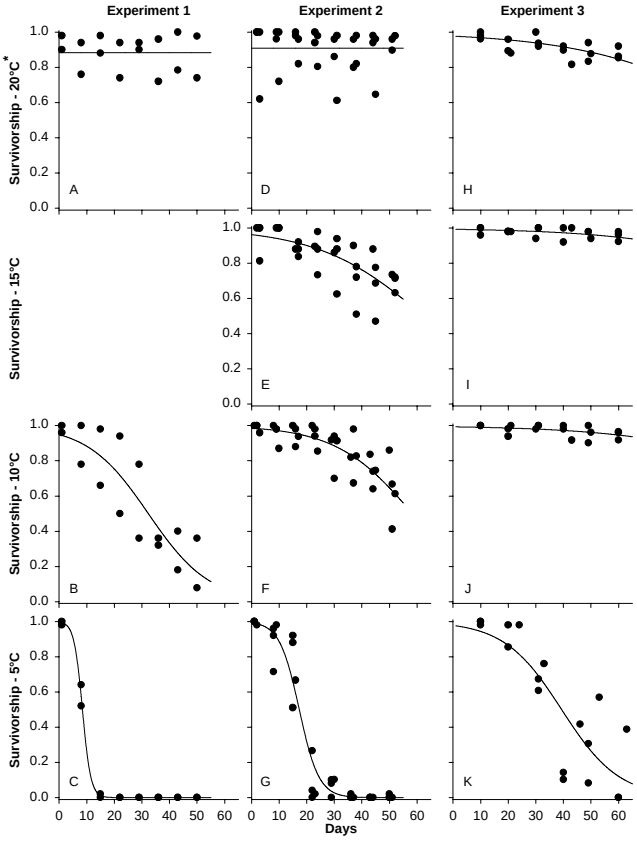

Figure 1. Proportionate survivorship of late-instar pink bollworm larvae as affected by time and temperature. Circles are observed values, and lines are expected values. *=Experiment 1 conducted at 20˚C; experiment 2 and 3 conducted at 22˚C.

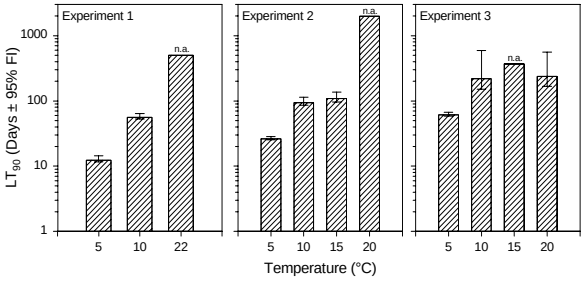

Figure 2. Time required to achieve 90% mortality (±95% fiducial limits) of late-instar pink bollworm larvae as affected by temperature.

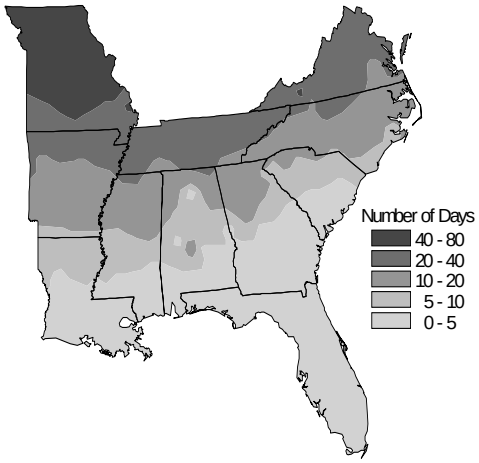

Figure 3. Median number of days with a maximum air temperature <5˚C.

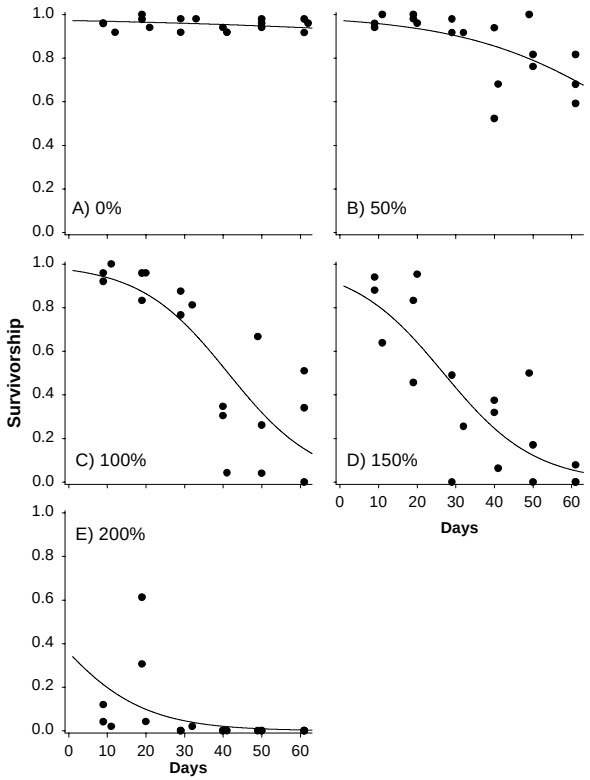

Figure 4. Proportionate survivorship of diapausing pink bollworm larvae as affected by time and gravimetric soil moisture.

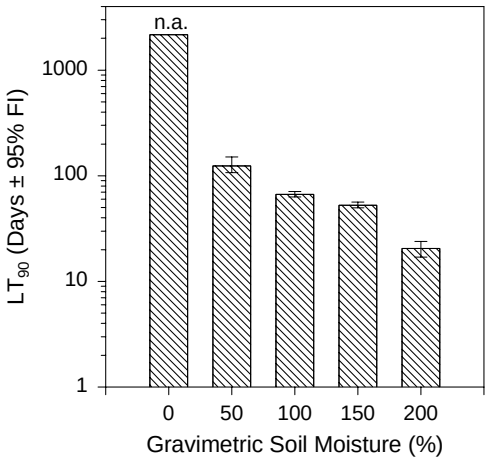

Figure 5. Time required to achieve 90% mortality (±95% fiducial limits) of late-instar pink bollworm larvae as affected by temperature.