Pink Bollworm: Diapause Larval Exit From Harvested Immature Cotton Bolls and Percentages Surviving to Moth Emergence

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Abstract

Pink bollworm (PBW), Pectinophora gossypiella (Saunders), diapause larval exit from immature green bolls and larval and pupal mortality after exiting bolls, were studied at Phoenix, AZ in the insectary. Diapause larvae exited immature bolls sporadically during January, February, and early March. Thereafter, exit from the bolls was more consistent and highest numbers emerged in late April, May or early June. Larval and pupal mortality were high during January to early February and March, decreased in mid-March through early June, and increased again in mid-June to early August. Larvae remained in immature bolls as long as 319 days after harvest. Moth emergence was significantly correlated to accumulated heat units (12.8 and 30.6°C lower and upper developmental thresholds).

Introduction

Pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), diapause larvae are vulnerable to cultural control methods. Most spring moth emergence from diapause larvae occurs during mid-March through mid-June. Cotton flower buds occur between mid-May and early June for cotton planted between 20 March and 20 April. Early-spring suicidal emergence that occurs when moths emerge in the absence of a reproductive host can range from 57 to 86% (Wene et al. 1961; Watson and Larsen 1968; Watson et al. 1970; Rice and Reynolds 1971; Slosser and Watson 1972; Bariola 1978). Planting dates in AZ based on a degree-day accumulations delay and reduce spring infestations by balancing the timing of 75% suicidal emergence against the first occurrence of fruiting forms suitable for PBW reproduction (Brown et al. 1992).

Diapause larvae overwinter in cotton bolls, plant litter on the ground, or in the soil, but little is known about larval activity from the time of diapause initiation until moth emergence occurs in the spring of the following year. We conducted studies in the insectary to determine patterns of diapause larval exit from cotton bolls and larval mortality after leaving bolls.

Materials and Methods

Over 20 thousand immature green cotton bolls were picked in cotton fields at Phoenix, AZ on 19 October. About 1500 bolls were randomly selected on 1 January and 50 were placed in each of 30 ventilated plastic sweater boxes (Fye 1976). The boxes with bolls were held in an outdoor, screen-covered, open-wall insectary. Bolls were first examined for PBW emergence on 1 January and weekly thereafter until 1 August. All living and dead larvae and

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pupae and adults were recorded. Living larvae and pupae were collected and placed individually in 28-ml capacity plastic cups with about 15 ml of agar base artificial PBW diet (Bartlett and Wolf 1985) to provide moisture. Plastic cups were examined each week for mortality.

Heat Units. Maximum-minimum and mean daily temperatures and heat units per day were obtained from the University of Arizona's AZMet database. The lower and upper thresholds of PBW development were 12.8° C and 30.6° C, respectively. The PBW developmental thresholds used were suggested by Huber (1981).

Statistical Analysis. Living and dead larvae and pupae were totaled for all 30 ventilated plastic sweater boxes. Numbers of dead larvae and dead pupae on each sampling date were recorded and percentage mortalities of the total numbers of PBW for that date calculated. Accumulated percentages of emerged moths in the insectary were regressed on heat units accumulated beginning on 1 January to determine potential temperature relationships to adult PBW moth emergence.

Results

Numbers of PBWs Exiting from Bolls and Percentages of Larval and Pupal Mortality. Numbers of diapause larvae exiting green bolls ranged from 5 to 200 during weekly periods from 1 January to 1 August (Figure 1A). Numbers emerging from bolls were low through 17 May, increased to a peak on 14 June and decreased thereafter on 1 August.

Larval mortalities ranged from 11.1 to 80% and averaged 42.7 ± 8.7% for larvae exiting bolls during 1 January to 8 March (Figure 1B). For the period 16 March to 7 June, larval mortalities ranged from 0.0 to 11.1% and averaged 2.6 ± 1.1%. Larval mortalities for 14 June to 1 August ranged from 7.7 to 100.0% and averaged 40.6 ± 9.7%. Pupal mortalities (Figure 1C) were lower ranging from 0.0 to 50.0% ($\bar{x}$ = 15.5 ± 5.1) from 1 January to 8 March and 0.01 to 32.1% ($\bar{x}$ 7.9 to 2.3% from 16 March to 7 June and 0.0 to 50.0% ($\bar{x}$ = 29.2 ± 3.3%) from 14 June to 1 August.

Total larval and pupal mortalities show that maximum survivorship of the overwintering stages of moth emergence ($\bar{x}$ = 89.5 ± 2.4%) occurred during 16 March to 7 June (Figure 1D).

Accumulated Heat Unit Relationships to PBW Moth Emergence: Cumulative percentages of overwintering survival (moth emergence) were significantly correlated (r = 0.96) to the numbers of heat units accumulated beginning 1 January. The regression relationship ($r^2 = 0.99$) was also highly significant ($P \leq 0.01$; $n = 33$; df = 1, 31) (Figure 2). Fifty percent moth emergence occurred at 849 accumulated heat units (°C).

Discussion

Diapause enables PBW larvae to avoid adverse conditions of low temperature and lack of host material during winter months and to survive to reenter reproductive cycles under more favorable conditions during cotton cultivation. About 64% of the PBW larvae in cotton fields near El Paso, TX were reported to overwinter in cocoons in the soil (Chapman et al. 1960). At several locations in AZ, Wene and Sheets (1966) reported that 89% of the PBW larvae left bolls to overwinter in cocoons. Fullerton et al. (1975) reported that only 52 and 1% of the PBW larvae in infested bolls buried in the soil in the field in December remained in the bolls after burial for 1 and 5 months, respectively. The reason that PBW larvae leave the protection of bolls in winter and early spring remains unknown and is difficult to explain since initially during generation 4 or 5, increasing numbers of larvae remain in the bolls when temperature and photoperiod conditions that induce diapause begin to occur (Crowder et al. 1975, Henneberry et al. 1980). This is presumably for protection from adverse environmental conditions since higher overwintering survival occurs for those in bolls compared with those occurring in cocoons outside bolls (Wene et al. 1961). PBW larval exit from bolls in January to early March did not appear related to diapause termination since pupation did not occur thereafter for 32 to 197 days (data not shown). Possibly, the stimulation for exiting bolls is related to locating near the soil surface to facilitate spring moth emergence.

Male moths have been caught in pheromone-baited traps every month of the year in AZ (Henneberry et al. 1980) and in Southern California's Coachella Valley, (Kaae et al. 1977). Some moth emergence in these studies occurred in January and February from infested immature bolls collected in October and November of the previous year. These results may partially explain the moth trap catches in winter in the absence of cotton crops. Whether these moths were from diapause or non-diapause larvae remains unknown. Decreasing photoperiods and lower temperatures beginning in mid-September in AZ induce PBW diapause (Butler et al. 1978, Gutierrez et al. 1981). Non-diapause larvae have been well documented in the equatorial region between 10° north and south latitudes (Lukefahr et al. 1964). In more northern latitudes percentages of PBW diapause from November collected larvae is often less than 100% (Crowder et al. 1975, Beasley and Adams 1997). Total development times for PBW larvae and pupae at 15° and 20°C were reported to be 85 and 35 and 36 and 18 days, respectively (Butler and Henneberry 1976, Butler and Hamilton 1976). Also, PBW moths have been reported to live over 110 days at constant temperatures of 17.2°C and over 74 days at fluctuating temperatures averaging 19.2 °C (Butler and Foster 1979). Thus, PBW moths caught in December, January and February may be from early-terminated diapause larvae or from PBW larvae that do not diapause but develop at low rates because of low winter temperatures (Butler and Henneberry 1976). In the present studies, almost all larvae found in bolls were in the 4th instar for bolls harvested on 19 October. Moths emerged during the weeks of 6 January, 1, 8, and 15 February. These dates were 45, 71, 78, and 85 days, respectively, after bolls were harvested. Average daily temperatures (°C) for the months of November, December, January and February were 16.7, 11.1, 10.6, and 15.0, respectively. These results support both premises: (1) PBW moth emergence from larvae that do not diapause but develop slowly, or (2) moth emergence from larvae that diapause but break diapause under lower temperatures and shorter photoperiods than has been reported (Butler et al. 1978, Gutierrez et al. 1981, Gutierrez et al. 1977).

Preventing the development of diapause PBW larval populations or destroying them after they develop are highly successful cultural practice components of PBW management systems (Watson and Larsen 1968, Watson et al. 1973, Chu et al. 1996). Shortening the growing season to prevent development of diapause larvae in late-season bolls has not been totally acceptable in all cotton growing areas because of potential yield limitations. Thus, there is a need for continuing studies to refine and improve existing cultural methods and look for new approaches or modifications of crop management systems that are agronomically robust and more acceptable in more demanding and less flexible cotton production situations. The results of our current studies provide additional information on PBW diapause larval behavior, habitat relocation from harvested immature bolls, mortality of larvae and pupae and spring moth emergence. This information broadens our growing knowledge of PBW biology and ecology that is essential to the development of ecologically oriented control methods.

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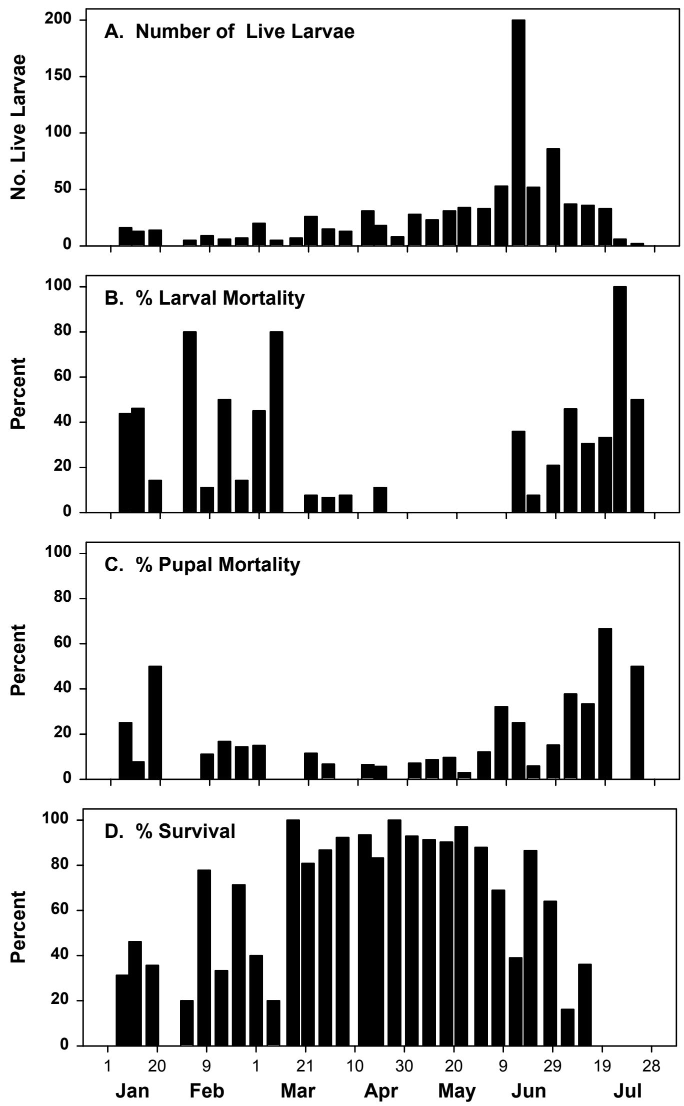

Figure 1. Number of live diapausing pink bollworm larvae emerged from immature green cotton bolls and mean percentages of larval and pupal mortality and percentages of immatures surviving to adult emergence.

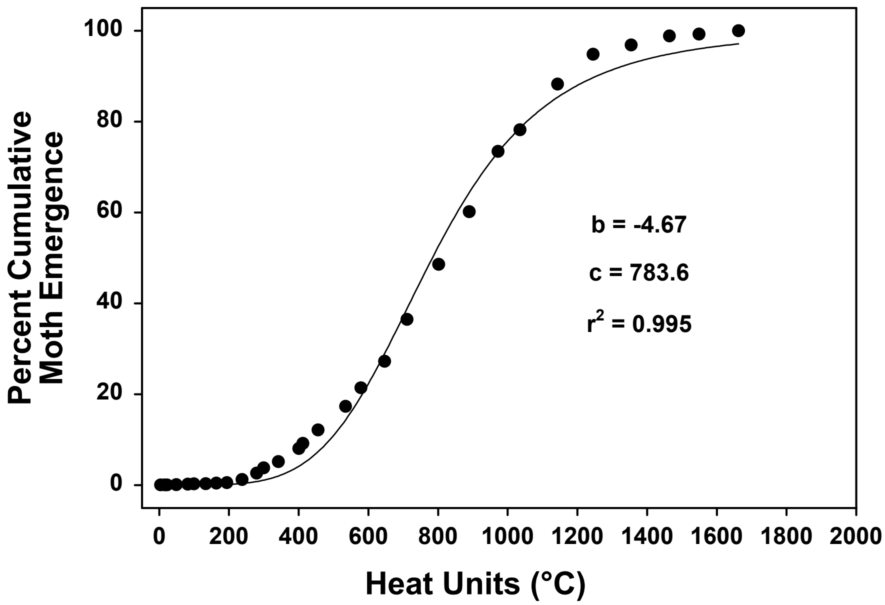

Figure 2. Accumulated percentages of spring pink bollworm moth emergence in the insectary in relation to accumulated heat units. Upper and lower development thresholds were 30.6 and 12.8°C, respectively. The emergence curves were effectively described by the formula:

$$Y = \frac{100}{1 + (x / c)^b}$$

Y = cumulative percent moth emergence, b = regression coefficient, x = cumulative heat units and c = median cumulative heat units for 50% emergence.