PREDICTING THE PHENOLOGY OF *HELIOTHIS VIRESCENS* (LEPIDOPTERA: NOCTUIDAE) ON TOBACCO USING ACCUMULATED DEGREE-DAYS

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ABSTRACT

Degree-day (°D) estimates were calculated between *Heliothis virescens* (F.) population peaks of adult males and between larval infestation peaks on tobacco in Florida. The mean °D between the first and second and between the second and third adult peaks for 3 years was 512 and 583, respectively. The mean °D between the first and second larval peaks was 550. Similarly, there was a mean of 554 °D between the first and second larval damage peaks on tobacco. From pheromone trap data collected over 5 years, there was a mean of 212 °D from the first catch of *H. virescens* males in the spring to the first adult population peak.

RESUMEN

Se calcularon estimados de grado-día (°D) entre el auge de poblaciones de adultos machos y entre el auge de infestación por larvas de *Heliothis virescens* (F).) en tabaco en la Florida. El promedio °D entre el primero y el segundo, y entre el segundo y el tercer auge de adultos en 3 años, fueron 512 y 583 respectivamente. el promedio °D entre el primero y el segundo auge larval fue de 550. Similarmente, hubo un promedio de 554 °D entre el primero y el segundo auge larval dañino al tabaco. En trampas de feromonas colectadas durante 5 años, hubo un promedio de 212 °D en la primera captura de machos de *H. virescens* en la primavera, hasta el primer auge de población de adultos.

The tobacco budworm (TBW), *Heliothis virescens* (F), is a serious pest of cotton and tobacco in the United States. Because improved methods of predicting insect populations are needed in pest management programs, interest has developed in constructing realistic population models for TBW (Stinner et al. 1974, 1975, Harstack et al. 1976). Knowledge of field developmental time between population peaks of adult TBW and the immature stages is useful in constructing these models to predict potential TBW infestations. Earlier studies used calendar days to measure developmental times of the immature stages of TBW in the field (Brazzel et al. 1953, Neunzig 1969). However, when predicting the duration of immature stages over a range of fluctuating temperatures, degree-days (°D)—a measure of cumulative temperature units—are sometimes more useful and accurate. Wang (1960) reviewed the early methods of attempts to integrate temperature over time to predict the phenology of organisms.

Hartstack et al. (1973) used blacklight traps to determine population peaks of *H. virescens* and *H. zea* in a cropping system of cotton, corn, grain sorghum, and pasture or hay crops so that they could estimate the mean generation times in °D. The accuracy in calculating °D was increased when Allen (1976) presented a method of correcting for local geographic bias. Using his method, Hogg & Calderon (1981) estimated the developmental times in °D of the larval and pupal stages of *H. virescens* and *H. zea* on cotton under field conditions in Mississippi. They reported °D means of 225, 212, and 234 for TBW larvae, female pupae, and male pupae, respectively. Mitchell (1986) stated that the more successful of the pheromone model systems developed to date have used °D as an important component and that simple systems, which can used with a minimum of technical training, can be developed using °D. The purpose of our study was to provide a method by which °D could be used to predict population peaks of TBW adults, larvae, and larval damage in tobacco fields in Alachua County, FL.

Materials and Methods

We determined °D between population peaks of both TBW adults and larvae and also between peaks of TBW damage in 12 tobacco fields. The °D values were calculated using the method with corrections for overestimating bias in Florida developed by Allen (1976). The minimum developmental threshold was assumed to be 12.6°C (Hartstack et al. 1973, Hogg & Calderon 1981). Climatological data for Gainesville, FL, were obtained from the University of Florida Agronomy Department and the National Oceanic and Atmospheric Administration. The weather station was located ca. 23 km from the tobacco fields.

Insect survey data were collected from four fields per year over a 3-year period (1978-1980). The tobacco fields (A-L) ranged in size from 2.3 to 7.6 ha (mean = 4.5) and were maintained by cooperating tobacco producers. Planting dates ranged from March 21 to April 10 (mean = April 1), and harvest began June 17 to July 3 (mean = June 24) of each year.

Adult male TBW populations were monitored in each field using cone-shaped traps constructed of 3.2 mm-mesh hardware cloth with an inner-truncated cone similar in design to those described by Hartstack et al. (1979). Each trap was baited with a laminated plastic Hercon strip containing 10 mg of a synthetic attractant for male TBW. The attractant used in 1978-79 (fields A-H) contained virelure [(*Z*)-11-hexadecenal/(*Z*)-9-tetradecenal, 16:1)] and the attractant used in 1980-85 (fields I-L) consisted of seven components [81.4% (*Z*)-11-hexadecenal, 2.0% (*Z*)-9-tetradecenal, 1.3% (*Z*)-9-hexadecenal, 3.2% (*Z*)-11-hexadecen-1-ol, 1.0% (*Z*)-7-hexadecenal, 9.5% hexadecanal, and 1.6% tetradecanal]. The traps were spaced equally within the fields at a density of one trap per ha except in fields C and D where 22 traps per ha were maintained throughout the growing season as a part of another study (Tingle & Mitchell 1981). All traps were maintained at plant height or at least 30 cm above ground level. Trapped moths usually were counted and destroyed twice weekly. Counts of feeding damage to plant terminals and larvae also were made twice weekly by visually examining 40 or 50 consecutive plants at each of five to nine preselected locations within each field (250 to 360 plants per field). After the tobacco plants were topped (i.e., flower buds removed), feeding damage assessments were made from secondary growth. The same plants were examined each time, but only fresh damage was recorded.

In addition to the trap and field data collected during 1978-1980, one or more survey traps for *H. virescens* were maintained continuously in this tobacco growing area from April 1, 1979 until January 30, 1986, except for the period August 20, 1981 to April 1, 1982. The accumulated °D from the first trap catch of TBW in the spring of each year (1980-1981 and 1983-1985) until the first detected peak of TBW adults were calculated from the trapping data.

Results and Discussion

According to pheromone trap catches of male moths, there were five adult TBW peaks each year beginning in mid-April with the last peak in early October. There were two larval peaks, as well as two damage peaks, in preharvest tobacco. The first TBW larval and damage peaks usually occurred in late April. Following a second adult peak

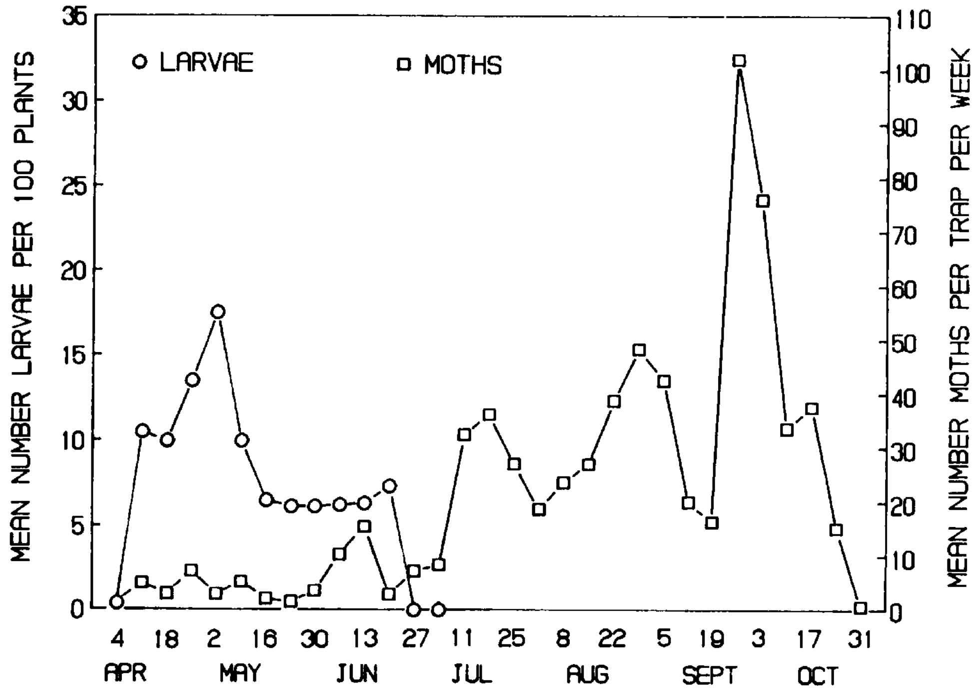

Fig. 1. Mean weekly counts of adult *Heliothis virescens* males collected per pheromone-baited trap and the weekly mean counts of *H. virescens* larvae per 100 tobacco plants in fields E, F, G, and H during 1979, Alachua County, Florida.

in early June, the second larval and damage peaks occurred in mid-June before harvest began (mid-June to early-July). The 1978 trap and field data are presented graphically in Figure 1 to illustrate the typical seasonal fluctuation of TBW adults and larvae in the tobacco fields.

Pheromone-trap catches of male TBW moths in tobacco over a 3-year period indicated means of 512 and 583 °D (50 and 41 days) between the first and second and between the second and third adult peaks, respectively (Table 1). Similarly, 550 and 554 °D (49 days) were calculated between the first and second larval and damage peaks, respectively. One trap per ha in the tobacco fields appeared to be sufficient for indicating adult population peaks. The trapping data obtained with a very high trap density (22 traps/ha) in fields C and D (1978) showed less distinct population peaks in early season when few moths were present.

Survey traps that were maintained in some fields past the 1978-1980 tobacco growing seasons indicated a fourth peak in the adult TBW population in late-August and a fifth peak in early-October, as reported by Jackson et al. (1984). The mean number of °D between the third and fourth adult peaks in fields A (1978) and E (1979) and in fields I and J in 1980 was 553 $\pm$28 (35 $\pm$ 3.0 days). Similarly, there was an accumulation of 511 $\pm$3 °D (37 $\pm$ 0.5 days) between the fourth and fifth peaks in field J (1980). Prediction of these later population peaks would be of greater importance in crops (e.g. cotton) that have longer growing seasons than tobacco.

We calculated from the 1980-1981 and 1983-1985 trap data a mean of 212 °D (35 days) from the first trap catch of TBW adults in March of each year to the first adult peak, occurring in April (Table 2). Potter et al. (1981) suggested using °D to predict emergence of TBW moths from overwintering pupae. Dependability of predictive models to forecast TBW emergence and population peaks on tobacco or other crops likely could be increased by using °D.

TABLE 1. MEAN CALENDAR DAYS AND ACCUMULATED DEGREE-DAYS (°D) BETWEEN PEAKS OF *HELIOTHIS VIRESCENS* ADULTS (MALES), LARVAE, AND TOBACCO PLANT DAMAGE CAUSED BY *H. VIRESCENS* LARVAE. ALACHUA COUNTY, FLORIDA.

Year	Days between peaks				°D between peaks			
	1 and 2			2 and 3	1 and 2			2 and 3
	Adults	Larvae	Damage	Adults	Adults	Larvae	Damage	Adults
1978[1]	481.2	51 ± 1.6	49 ± 1.5	43 ± 1.5	501 ± 15	604 ± 14	586 ± 19	622 ± 21
1979[2]	52 ± 2.3	50 ± 2.8	52 ± 4.0	38 ± 1.7	559 ± 16	550 ± 22	577 ± 39	531 ± 24
1980[3]	51 ± 1.5	47 ± 2.9	47 ± 2.7	43 ± 0.9	476 ± 16	496 ± 9	498 ± 21	597 ± 24
Mean	50	49	49	41	512	550	554	583
± S.E.	± 1.2	± 1.2	± 1.5	± 1.7	± 25	± 31	± 28	± 27

[1]Fields A-D.
[2]Fields E-H.
[3]Fields I-L; survey traps placed in fields I and L too late in season to detect first adult peak.

TABLE 2. CALENDAR DAYS AND ACCUMULATED DEGREE-DAYS (°D) FROM FIRST TRAP CATCH OF *HELIOTHIS VIRESCENS* MALES IN SPRING UNTIL THE FIRST ADULT POPULATION PEAK IN A TOBACCO GROWING AREA OF ALACHUA COUNTY, FLORIDA. 1980-1981 AND 1983-1985.

Growing season	TBW trap catch dates		°D to first adult peak	
	First moth	First peak	Days	°D
1980	3-13	4-10	28	207
1981	3-20	4-17	28	193
1983	3-4	4-15	42	232
1984	3-14	4-23	40	207
1985	3-9	4-15	37	225
Mean	3-12	4-16	35	212
±S.E.	±3	±2	±3	±7

In summary, cumulative °D between population peaks of TBW adults or larvae in tobacco provide a means for predicting the occurrence of possible future infestations of this pest on tobacco. Similarly, there is a close relationship between the accumulated °D and sequential plant damage peaks in tobacco caused by TBW larvae. Although the variations in °D between peaks were somewhat higher than we would have liked, these variations probably would have been less had the data been collected more frequently than the one to three times per week. Our sample intervals did not permit statistical comparison of °D and calendar days for predicting TBW population and damage peaks. However, the mean °D values presented in Table 1-2 do provide reliable indicators, which can used by crop production consultants and others advising on the control of TBW in tobacco. Therefore, pheromone trap catch data can be used to forecast the occurrence of TBW infestations in tobacco. The timing of larval population peaks and potential damage to tobacco by the TBW also can be predicted at least one generation in advance using °D data. Thus, pest management advisors can decide in advance the necessity for damage monitoring and the type of control needed. Optimal timing of chemical control can be determined by using pheromone trap data and °D summations as have been reported for the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Gargiullo et al. 1985). The possible reduction in the quantity of pesticide used and the frequency of application now required to control TBW in tobacco also would enhance opportunities for integrating biological control strategies with conventional methods of control.

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