FEEDING OF TOBACCO HORNWORM LARVAE UNDER DIFFERENT LIGHT CONDITIONS AS INDICATED BY FECAL EVACUATIONS[1]

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Abstract. The periodicity of fecal evacuations of tobacco hornworm larvae (*Manduca sexta*) was monitored throughout the total larval phase in constant light, constant darkness, and a fall rhythm of light and darkness. By observation of feeding behavior and fecal evacuations of larvae, the time relationship of fecal evacuation and ingestion was recorded. The interval between initial ingestion and first evacuation averaged 3.75 hr. During the intervals between molts the larvae actively fed in periods averaging 14 min. The average length of feeding periods between molts was 58 hrs and the length of molting periods 22 hrs. The total larval phase covered 375 hrs in the fall light-dark cycle, 358 hrs in continuous darkness, and 407 hrs in continuous light. The total larval phase and the total numbers of fecal pellets evacuated in the different light regimes were not significantly different.

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In studies on the biology of the tobacco hornworm (*Manduca sexta*) we made efforts to establish a time schedule of feeding activities. Because of the impracticability of continuous monitoring of feeding behavior, an indirect approach was used. This involved mechanical monitoring of fecal evacuations and translation of these evacuations to indicate feeding activities. In the analysis that follows fecal evacuations were thus translated to represent feeding activity. Results are reported on tests made in constant light, constant darkness, and a fall cycle of light and darkness.

MATERIALS AND METHODS

The larvae were fed artificial diet similar to that described by Yamamoto (1969). The diet was allowed to solidify in plastic cups having toothpicks inserted through their sides to prevent the diet from dropping out when the cups were inverted. A toothpick was also inserted in the center of the diet to provide a perch for the larva. The newly hatched larvae were placed on the surface of the diet, and the cups were inverted over a platform which extended outwardly between the upper and lower winding spools on a recorder. The recording paper moved over and under the platform at the rate of two inches per hour, and the fecal pellets fell onto the moving cross-lined paper. The time of evacuations was read from the paper and recorded to the nearest 10 min. intervals. To anticipate loss of larvae, 12 newly hatched larvae were started in each of the tests, but complete data could be obtained only for a single larva per light treatment. Except for four brief interruptions in each test when the diet was replenished, a continuous record was obtained for one larva in each test. To correlate ingestion with egestion, fourth and fifth instar larvae were observed with a reading glass. The treatments consisted of constant light, constant darkness, and a fall rhythm of 60% light and 40% darkness. The temperature was maintained at approximately 26°C and the relative humidity at 80%.

RESULTS

In seven observations of fourth and fifth instar larvae, an average of 3.75 hr (1.58 to 4.58 hr) was required for food to pass through the digestive tracts of the larvae. Thus, feeding started about 3.75 hr before the first fecal pellet appeared and ceased the same length of time before the last pre-molt pellet appeared. Accordingly, with a backward adjustment of 3.75 hr, records for fecal evacuation show feeding activities.

In nine observations, fourth and fifth instar larvae fed continuously an average of 14 min (range 8 min 10 sec to 18 min 20 sec). Thus, about one fourth of the

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feeding time was spent actively feeding and three-fourths resting. During feeding periods, fecal pellets were evacuated an average of every 52 min, both by larvae in continuous light and in the fall light-dark cycle and every 55 min by larvae in continuous darkness. Larvae in continuous darkness evacuated slightly more fecal pellets (371) than those in continuous light (353) and both of these more than those in the fall light-dark cycle (311).

The duration of the larval phase varied from 358 to 407 hr, with the period longest among larvae in continuous light, medium among larvae in the fall light-dark cycle, and shortest among larvae in continuous darkness (table 1). Larvae in continuous darkness and in the fall light-dark cycle spent about the same length of time feeding. Larvae in continuous darkness differed from those exposed to other light-dark treatments chiefly in spending less time molting, 71 hr as compared with 90 hr in the fall light-dark cycle and 92 hr in continuous light.

Light treatments were compared with respect to number of pellets, using an analysis of variance for a one-way classification. The stadia within light treatments served as the source of an estimate of experimental error. It was necessary to fit a regression of number of pellets on the time in stadia variable and use the deviation from regression (pooled over the three light treatments) as an estimate of experimental error. After fitting these regressions, the pooled deviation from regression mean square was only slightly smaller than the mean square for light treatments. Therefore, it was concluded that light treatments did not have a significant effect on the feeding behavior of the larvae as expressed by the number of pellets produced.

A definite relationship between number of pellets and time occurred in the continuous-dark category. The F value for linear regression in this category was 22.0. F values for linear regression in the fall light-dark cycle and continuous light categories were 3.0 and 2.9, and were not significant at the 5% level.

The average length of time larvae spent in molting was not different for the three light treatments (means: 18, 23, and 23 for continuous dark, continuous light and the fall light-dark cycle, respectively).

Figure 1 shows the schedule of fecal evacuations and molting periods for a larva in the fall light-dark cycle. Since statistical tests showed no significant differences in pellet counts and molting behavior under the different light regimes, a chart is shown for only one light regime. The data in table 1 for fall light-dark cycle can be shown to correspond to results presented graphically in figure 1.

In the various light regimes the feeding periods were from 38 to 110 hr long (average 59), with the longest in the fifth instar. In instars earlier than the fifth, the feeding periods were from 38 to 59 hr long, with an average of 50. The time between fecal evacuations ranged from 30 to 67 min, with an average of 21.

TABLE 1

Numbers of hours in molting and feeding periods and numbers of fecal pellets in different light regimes.

Stadium	Fall Rhythm			Continuous Light			Continuous Dark		
	Feeding	Molting	No. Pellets	Feeding	Molting	No. Pellets	Feeding	Molting	No. Pellets
1st	57	17	73	41	18	64	44	14	81
2nd	43	20	54	46	22	73	38	19	45
3rd	47	22	49	59	25	58	51	19	50
4th	57	31	53	59	27	58	52	19	62
5th	79	—	82	110	—	100	102	—	137
Mean	57	23	62	63	23	71	57	18	75

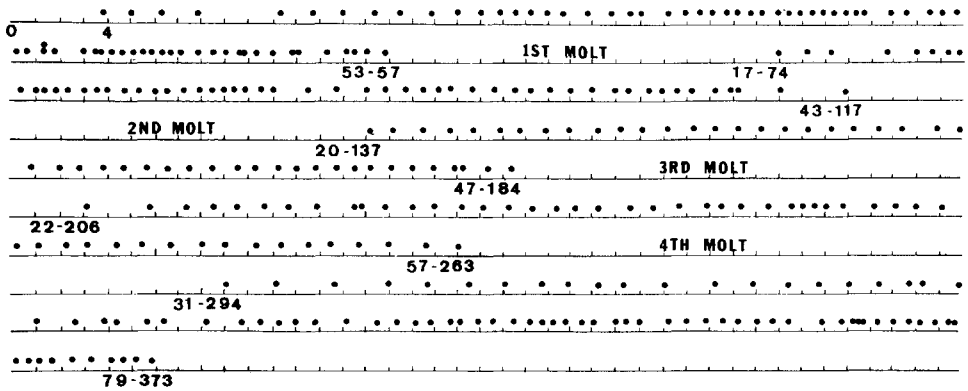

FIGURE 1. Schedule in hours of fecal evacuations (dots) and molting periods of a tobacco hornworm larva in fall light-dark cycle. The first number of the number-pairs is the length in hours of the preceding feeding or molting period; the second number is the cumulative length of time in the larval phase to the points indicated.

The total number of fecal pellets per instar varied from 45 to 137, with the largest number in the fifth instar. The average number was 69. In instars before the fifth, the total number of fecal pellets varied from 45 to 81, with an average of 60 pellets per instar.

DISCUSSION

Results obtained in this study showed that, with food constantly available, *Manduca sexta* larvae fed independently of ambient light. This observation agrees with the conclusion by Heinrich (1971) indicating that light was not essential for feeding by these larvae. Casey (1976) also reported that *Manduca sexta* larvae fed during both night and day in Kentucky tobacco fields.

Jones and Thurston (1970) reported that a *Manduca sexta* larva processes 1400 cm^2 of tobacco leaves in the course of its development, with 85% of this being processed in the fifth instar. Our study indicated that 25.6% of the total time in the larval phase and 32.9% of the feeding time was spent in the fifth instar. Of the total of 1039 fecal pellets evacuated in the total larval phase (all treatments), 31% by count were evacuated in the fifth instar. In addition, the fecal pellets were increasingly larger in successive instars.

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