Table 8. The Egg Laying Records of Several Armyworm Moths, Knoxville, Tennessee, 1957

Female number	Date emerged	Dates of oviposition	Egg mass	Number of eggs	Daily total	Lifetime total	Date of death	Preoviposition period	Oviposition period	Postoviposition period
548	Mar. 31	Apr. 3	A	169	169		Apr. 15	3 days	6 days	7 days
		4	B	210	210					
		5	C	225						
			D	142	367					
		6	E	68	68					
		7	F	21	21					
		8	G	33	33	868				
557	Apr. 4	Apr. 8	A	106			Apr. 15	4 days	3 days	5 days
			B	172	278					
		10	C	110						
			D	128	238	516				
562	Apr. 20	Apr. 23	A	133			Apr. 30	3 days	7 days	1 day
			B	239						
			C	39						
			D	95						
			E	81	587					
		24	F	68						
			G	55	124					
		25	H	224						
			I	176	400					
		26	J	137						
			K	85	222					
		27	L	136	136					
		29	M	32						
			N	152						
			O	106	290	1759				

Table 9. Number of Egg Masses and Number of Eggs per Mass Deposited by Females of *Pseudaletia unipuncta* During Each of the Five Oviposition Periods, 1957.

Flight Number	Period of Observations	Number of Masses	Number Females Observed	Number of Egg Masses Deposited by One Female: Range	Ave.	St. Error	Number of Eggs Per Mass: Range	Ave.	St. Error
I	Mar. 11-May 20	84	15	1-16	5.6	± 1.19	5-239	110.6	± 6.10
II	Jun. 3-Jun. 24	43	11	2-9	4.8	± .74	15-400	130.2	± 1.89
III	Jul. 15-Aug. 12	88	17	1-16	5.2	± .92	10-345	90.0	± 7.54
IV	Aug. 29-Sept. 23	78	17	1-10	4.6	± .71	3-340	101.3	± 1.00
V	Oct. 20-Nov. 18	34	8	1-6	4.3	± .60	35-260	139.0	± 9.60
Totals	Mar 11-Nov. 18	327	68	1-16	4.9	± .40	3-400	108.4	± 3.88

Table 10. Number of Eggs Deposited by Females of *Pseudaletia unipuncta* During Each of the Five Ovipositions Periods, 1957.

Flight Number	Period of Observations	Number Females Observed	Duration of Oviposition in Days: Range	Ave.	St. Error	Daily Egg Production Per Female: Range	Ave.	St. Error	Total Egg Production Per Female: Range	Ave.	St. Error
Ia	Mar. 11-May 20	15	1-9	4.0	± .063	5-587	154.7	± 21.3	5-1759	619.2	± 131.4
II	Jun. 3-Jun. 22	9	1-9	5.3	± 0.85	15-732	117.3	± 16.4	131-1033	622.1	± 107.0
III	Jul. 15-Aug. 8	29	1-10	4.4	± 0.37	6-377	62.0	± 6.8	58-1345	273.2	± 60.2
IV	Aug. 29-Sept. 23	17	1-7	4.0	± 0.45	6-380	116.2	± 10.3	15-1344	464.7	± 89.1
V	Oct. 20-Nov. 18	8	1-10	4.5	± 1.04	37-392	131.3	± 4.7	37-1021	590.7	± 41.6
Season Totals	Mar. 11-Nov. 18	78	1-10	4.3	± 0.24	5-732	105.6	± 5.4	5-1759	454.3	± 41.56

aMoths of this flight were all wild caught and some had undoubtedly deposited eggs before confined.

figure is 737 eggs counted in the ovaries of a female. Slingerland (1896) gives the same figure and is obviously quoting Riley, and Davis and Satterthwait (1916) state that the largest number of eggs obtained from a single female in their work was 254. The writer has recorded the number of eggs deposited by each of numerous specimens. The number of eggs deposited averages higher than the maximum figure given by Davis and Satterthwait, and the average approaches the extreme figure of other authors. The maximum number of eggs obtained by the writer from a single female was 1759, but it must be noted that this was a captured specimen which oviposited during the first night of captivity and could have conceivably deposited some eggs prior to her capture. At any rate, the potential of the species would probably be in the neighborhood of 2000 eggs. Data on the number of eggs deposited by the moths per day and during life are presented for all 1957 broods in table 10. From the data given in this table, it can be seen that the armyworm moth, in confinement during 1957 in Tennessee, had oviposition periods which ranged from one to ten days and averaged 4.3 days. The number of eggs deposited by a single female per day ranged from five to 732 and averaged 105.6. The lifetime egg production of the moth varied from a low of five to a high of 1759 and averaged 454.3 eggs.

Light and Oviposition

Preliminary experiments were conducted to determine the effect of light on oviposition. Two gravid females were placed, separately, in one-gallon wide-mouth jars of the usual type and kept in constant light. Two gravid females were likewise isolated in jars of the same type, which had been painted black with poster ink so that no light could enter. These dark jars were kept in constant darkness. All other factors were kept constant. All of the moths had normal life spans, but in no case were eggs deposited. Dissection after death yielded numerous eggs from the body of each moth, more than one thousand in each constant-light moth and one constant-dark moth, and nearly two hundred in the remaining constant-dark moth. No conclusions can be drawn from the use of so few specimens, but the indication is that the moth requires for oviposition a photoperiod of alternate light and darkness. It is planned to conduct further experiments on the effect of this and other physical factors on the habits of the moth in future studies.

Time Elapsing Between Emergence and Oviposition

To determine the interval of time between emergence of the female moth from the pupa and oviposition, a series of female moths in each brood was isolated with one or two males, all of which had emerged on the same day. The first day of egg deposition was recorded for each female. Table 11 shows some

Table 11. Time Elapsing Between Emergence and Oviposition of *Pseudaletia unipuncta* at Various Times During 1957 in Tennessee.

Specimen number	Date of emergence	Date of oviposition	Length of interval in days
536A-6	April 23	April 29	6
I-6	April 29	May 6	7
536A-5	April 30	May 8	8
I-4	May 8	May 14	7
22	June 3	June 8	5
24	June 4	June 8	4
22A	July 15	July 18	3
105	August 29	September 3	5
116	September 6	September 11	5
130	September 9	September 13	4

cage records of female moths concerning the time interval between emergence and oviposition during different months of the year. Table 12 gives the extreme and averages for each 1957 brood. The period ranged from three to seventeen days and averaged 6.05 days for the entire season. Standard errors of the means indicate little difference in the average of this period from brood to brood.

Longevity of the Moth

The average life-span of the armyworm moth in captivity is in the neighborhood of ten days, but moths have been kept alive by the writer for three weeks and longer. In the insectary rearing of 261 moths on which longevity records were kept, the length of life ranged from one to twenty-seven days and averaged nine days for males and ten days for females. The results of longevity records are given in table 13.

Sufficient liquid food and atmospheric moisture were found to be the most important factors influencing the longevity of adults. Extreme summer temperatures were of no consequence except in the absence of sufficient humidity. In July, 1957, a high mortality rate among caged moths on extremely hot days was corrected by draping a wet towel over the cage.

Table 12. Records of Length of Time Between Emergence and Oviposition of *Pseudaletia unipuncta* During Each of the Five Flight Periods in Tennessee, 1957.

Flight number	Period of observations	Number of females observed	Length of interval (days)		
			Range	Ave.	St. Error
I	Mar. 11-May 20	4	6-8	6.8	± 0.15
II	Jun. 3-Jun. 24	10	3-10	5.9	± 0.70
III	Jul. 15-Aug. 12	23	4-10	5.6	± 0.35
IV	Aug. 29-Sept. 23	17	3-14	5.9	± 0.73
V	Oct. 20-Nov. 11	7	5-17	7.8	± 1.68
Totals	Mar. 11-Nov. 11	61	3-17	6.05	± 0.32

Table 13. Longevity in Days of Adults of *Pseudaletia unipuncta* During Each of Five Flight Periods in Tennessee, 1957.

Flight number	Period of observations	Number observed		Longevity: Males			Longevity: Females		
		Males	Females	Range	Ave.	St. Error	Range	Ave.	St. Error
I	Mar. 11-May 20	8	9	3-19	11.4	± 1.41	3-18	11.2	± 1.43
II	Jun. 3-Jun. 24	21	11	4-18	10.2	± 0.83	4-24	12.2	± 1.85
III	Jul. 15-Aug. 12	56	47	1-24	8.5	± 0.81	2-22	8.5	± 0.51
IV	Aug. 29-Sept. 23	47	31	3-20	8.3	± 0.58	3-20	8.5	± 0.68
V	Oct. 20-Nov. 11	12	19	5-22	11.7	± 1.51	5-27	15.0	± 1.49
Totals	Mar. 11 Nov. 11	144	144	1-24	9.0	± 0.41	2-27	10.1	± 0.42

THE EGG

Description (see figure 4)

The egg of the armyworm moth is perfectly spherical and measures from 0.6 to 0.7 mm. in diameter. Under low magnification the surface appears smooth, but at 54X and above the shell can be seen to be marked with very fine ridges forming an irregular pattern. The color of the egg when first deposited varies from white to pale yellow, becoming a dark yellow after about twenty-four hours. Immediately preceding hatching, the egg becomes from dark gray to black resulting from the dark head of the larva showing through the shell. Infertile eggs never progress beyond the pale yellow color phase.

Length of Incubation Period

Between March 25, 1957, and November 23, 1957, at Knoxville, Tennessee, a total of 271 egg masses was obtained on which incubation period records were kept. During this time the shortest period of incubation was three days, the longest twenty-four days, and the average 6.4 days. The longest periods occurred during a cool spell in mid-April and in fall, while the shortest occurred in mid-summer. Table 14 gives data showing the length of the incubation periods during each of the five 1957 broods. The temperature influence on the incubation period may be seen by examining the mean temperatures for each period given in the table.

Fertility and Hatching Percentages

Fertility of the egg of an armyworm moth may be ascertained by the darkening color of the egg. Egg masses or individual eggs in a mass which do not become deep yellow by the second or third day after deposition are always found to be infertile. Most of the eggs in a mass from a fertilized female hatch, however, almost invariably a small percentage fails to hatch. This is probably not due to infertility of the eggs in question, but rather to injury by early emerging larvae of the same mass.

Frequently during extremely hot, dry periods the entire egg production of a female moth fails to hatch, or certain masses do not hatch while other masses from the same female do hatch. The failure of all egg masses of a female to hatch is undoubtedly due to the failure of the moths to mate at high temperature and low humidity rather than to the effect of these factors on the eggs themselves, since moisture supplied to such egg masses upon such deposition fails to induce hatching. When some egg masses of a female hatch while others do not, deficient moisture is apparently the limiting factor since a portion of such an egg mass supplied with moisture hatches, while the other portion, without added moisture, fails to hatch. Table 15 gives the hatching percentages of eggs for all five broods of 1957. Data in this table indicate a nearly complete hatching percentage of eggs

Table 14. Length of Incubation Period of Eggs of *Pseudaletia unipuncta* During Each of the Five Broods, 1957.

Brood number	Period of observations	Number of egg masses	Mean tempera-ture	Incubation period in days Range	Ave.	St. error
I	Mar. 25-May 13	90	64.3°F.	3-15	6.6	± 1.07
II	Jun. 8-Jun. 21	52	78.6°F.	3-5	3.6	± 0.03
III	Jul. 19-Aug. 10	45	79.7°F.	3-4	3.2	± 0.06
IV	Aug. 30-Sept. 21	43	76.9°F.	3-5	3.6	± 0.09
V	Oct. 25-Nov. 23	41	52.9°F.	6-24	16.0	± 0.77
Totals	Mar. 25-Nov. 23	271		3-24	6.4	± 1.62

during the cool months of spring and fall while the hot months of summer show a relatively low hatching percentage. The influence of temperature on egg hatching is indicated. As discussed above, this influence is apparently closely associated with moisture requirements of the moths and the eggs.

The chi-square test for homogeneity indicates that the samples are not from a homogeneous population, *i. e.,* there is not a uniform probability for egg hatching from brood to brood.

THE LARVA

General Description of the Mature Larva (figures 9, 10, and 11)

This description is a modification of that of Crumb (1927).

Head 3.0 to 3.5 mm. broad. Body about 30-35 mm. long and 5.5-6.5 mm. broad at broadest point; skin smooth; general color varying from red through pinkish and pale gray to the more usual dark gray or greenish-gray. The usual coloration as follows: ground color yellowish or grayish or greenish-gray, more or less tinged with pinkish; dorsal area with setigerous tubercles I and II strongly infuscated (figure 11, I and II); setigerous tubercle II with a narrow black stripe near its base; subdorsal area pale, slightly infuscated; spiracular area heavily infuscated or black including the spiracle; sub-spiracular area pale tinged with pink; spiracles entirely black; head pale gray slightly tinged with brown and black submedian stripes and reticulation; frontal

Table 15. Hatching Records of Eggs of *Pseudaletia unipuncta* During Each of the Five Oviposition Periods, 1957.

Flight number	Period of observations	Number of egg masses	Total eggs	Number hatched	Per cent hatched
I	Mar. 11-May 20	84	9,308	9,127	98.0
II	Jun. 3-Jun. 24	53	5,599	4,392	78.4
III	Jul. 15-Aug. 12	125	11,189	3,270	29.2
IV	Aug. 29-Sept. 23	122	11,955	7,477	62.5
V	Oct. 20-Nov. 11	34	4,726	4,618	97.7
Totals	Mar. 11-Nov. 11	418	42,777	28,884	67.5

Chi-square for homogeneity = 13,676; probability = <.0001

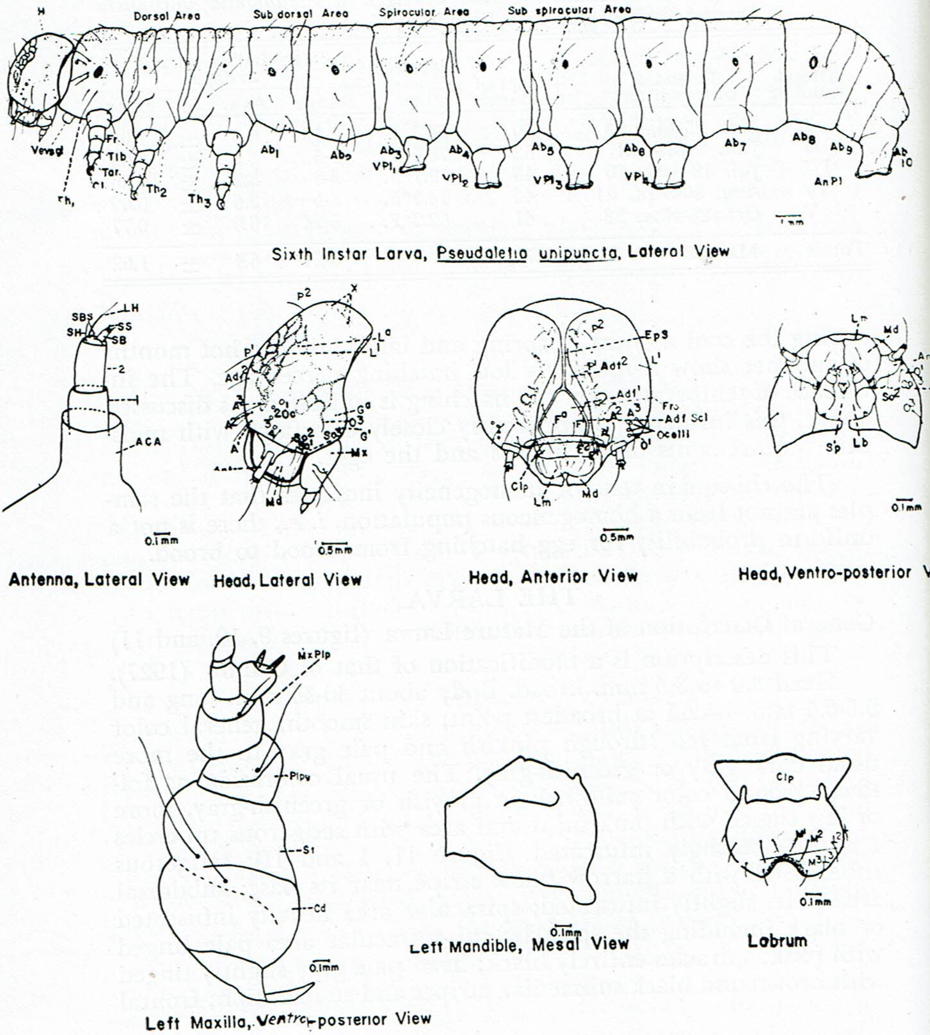

Fig. 9. External features of the sixth instar larva of *Pseudaletia unipuncta* with details of the head and mouthparts.

Abbreviations: Ab-abdominal segment; ACA-antacoria; Adf Scl-adfrontal sclerite; AnPl-anal proleg; Ant-antenna; Cd-cardo; Cl-tarsal claw; Clp-clypeus; EpS-Epicranial suture; Fr-femur; Frs-frons; H-head; LH-long hair (sensillum trichodeum); Lb-labium; Lm-labrum; Md-mandible; Mx-maxilla; MxPlp-maxillary palpus; Oc-ocellus; Plpg-palpiger; SB-sensillum basiconicum; Sp-spinneret; SS-sensillum styloconicum; St-stipes; Tar-tarsus; Th-thoracic segment; Tib-tibia; Vevgl-ventral eversible gland; VPl-ventral proleg. *Setae and punctures*: Adf-adfrontal; F-frontal; G-genal; L-lateral; M-median; O-ocellar; P-posterior; SO-subocellar; X-ultraposterior.

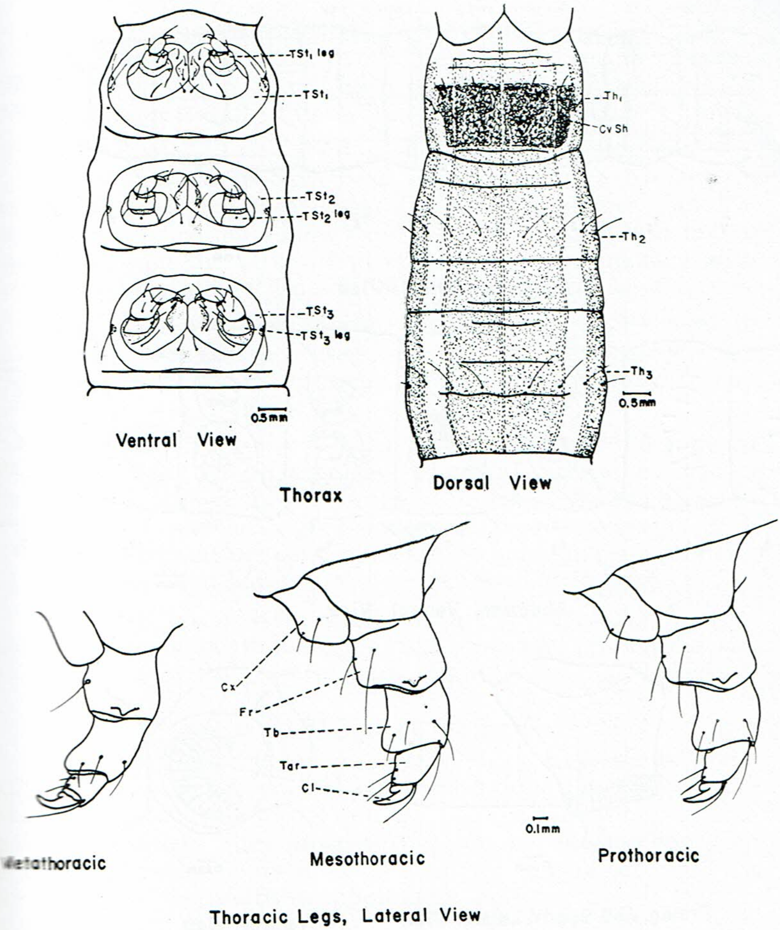

Fig. 10. External features of the thorax of the sixth instar larva of *Pseudaletia unipuncta.*

Abbreviations: Cl-tarsal claw; CvSh-cervical shield; Cx-coxa; Fr-femur; Tar-tarsus; Tb-tibia; Th_1-prothorax; Th_2-mesothorax; Th_3-metathorax; TSt-thoracic sternum.

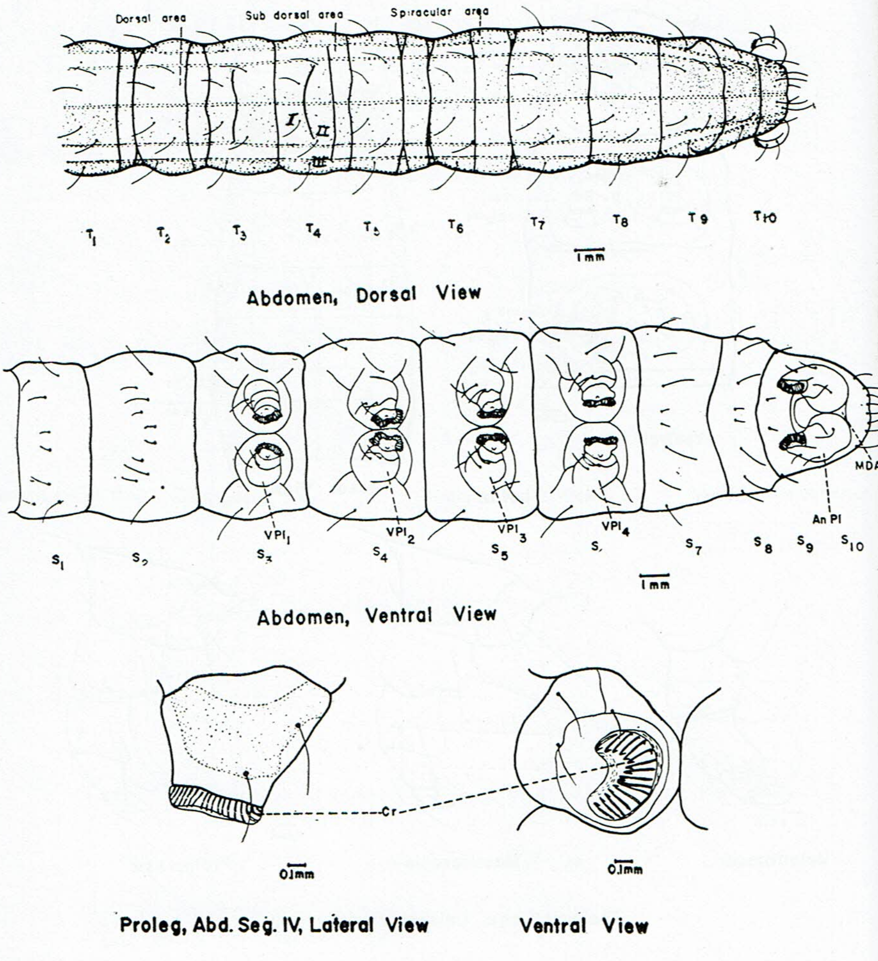

Fig. 11. External features of the abdomen of the sixth instar larva of *Pseudaletia unipuncta*.

Abbreviations: AnPl-anal proleg; Cr-crochets; MDA-median depressed area; S_1-S_{10}-abdominal sterna 1 to 10; T_1 to T_{10}-abdominal terga 1 to 10; VPl-ventral proleg; I, II, III-setigerous tubercles I, II, and III.

punctures (figure 9, Fa) nearly always below the line of the frontal setae; cervical shield concolorous with adjacent parts but with three pale lines strongly outlined in black (figure 10, Cv Sh).

Description of Other Instars

The newly hatched armyworm larva head capsule measurement averages .35 mm· in width; the body length averages 1.8 mm. The color is dull white except for the head which is brownish-black. The front two pairs of prolegs are underdeveloped.

The second instar larva head capsule averages .57 mm. in width; the body length averages 1.8 mm. Prominent color features are the medium yellow head with black ocelli and brown mandibles, and the yellowish-green tinge of the abdomen with very faint longitudinal lines more characteristic of later instars.

The third instar larva head capsule averages .94 mm. in width; the body length averages 7 mm. There is little color change from the preceding instar except in the increased prominence of the longitudinal stripes.

The fourth instar larva head capsule averages 1.5 mm. in width; the body length averages 11 mm. The head becomes a darker color, approaching brown, with reticulations so characteristic of the mature larva· The abdomen takes on a deeper grayish-green color and the cervical shield becomes more prominent. Other features and habits are those of the mature larva.

The fifth instar larva head capsule averages 2.3 mm. in width; the body length averages 18-20 mm. The general description fits that of the mature, sixth instar larva already given.

General Habits of the Larva

Upon hatching, the young "worms" devour the shells of the eggs from which they hatched and remain quiet for several hours thereafter. After this initial rest period, the larvae begin food-getting activities. They move with a looping motion resulting from the underdevelopment of the first two pairs of prolegs. First instar larvae are positively phototactic and because of this reaction they are commonly found at the uppermost part of plants shortly after hatching. This response is apparently a useful one since the young larvae are dependent upon tender plant tissue such as that found at the growing tips. The first stage "worms" skeletonize the leaves on which they feed (figure 4). When disturbed, the young armyworm larva drops suspended from a silken thread which it spins. This habit undoubtedly serves to some extent in dispersion and as a means of escape. After dropping, the "worms" are seen to bend to the characteristic C-shaped curl of the cutworms, and remain motionless in that position for some time. The second instar larvae do not differ in habits from those of the first. The habit of looping and skeletonizing is lost in the third instar. Instead, the larvae crawl about with the venter in contact with the substrate and eat holes in the leaves from the edges inward to the mid-rib. When disturbed, larvae in this and subsequent insars fall to the ground without the benefit of the silken thread and assume the C-shaped curl. The third through sixth instars all have common habits. Larvae in these instars are active at dusk and dawn and do most of their feeding at night. During the day they remain concealed under foliage of host plants or under debris in the field. This habit of concealment is one of the most important factors in the armyworm's ability to escape early detection. Not until the "worms" have matured and begun their gregarious march for additional food are they conspicuous. Another important factor in their escape from early detection is the relative amount of food consumed by the various instars. Davis and Satterthwait (1916) found that for a total of 108 individual armyworms, the average amount of foliage consumed per worm was 41.394 square inches and the average for the same individuals in the sixth instar alone was 34.128 square inches, the amount of foliage consumed by the sixth instar being 80 per cent of all foliage eaten during the entire larval period. This remarkable voracity of the armyworm in its last larval instar along with its concealment by day, helps to explain its sudden discovery in such enormous and destructive numbers only when it is nearly full-grown.

After the armyworm larva has consumed sufficient food, it crawls into the soil where the prepupa forms the pupal cell and molts to form the pupa.

The capacity of the armyworm for injury is enormous. Davis and Satterthwait (1916) state that according to feeding records, five armyworm larvae could devour two corn plants two feet high. These authors state that 8,890 corn plants to the acre would require 21,473 "worms" to destroy an acre of corn two feet high. This represents the potential progeny of not more than 40 moths.

Duration of Larval Life

The duration of larval life is influenced mainly by prevailing temperatures and availability of food. The period is greatly extended during winter months and much abbreviated during the warmer parts of the year. The writer has observed complete larval development from eclosion to pupation in as few as twenty days in June and July, while he has recorded an individual specimen remaining in a single instar, the fifth, for 130 days, during the winter months. Another specimen, observed from eclosion to pupation during winter months, had a larval development period of 118 days.

Aside from the overwintering brood, larval development was completed in from twenty to forty-eight days and averaged about twenty-eight days.

Table 16. Duration of the Various Instars and Length of Larval Life in Five Groups of *Pseudaletia unipuncta* June 12, 1957, Through July 12, 1957.

Instar	Length of instar in days — Group I	II	III	IV	V
First	2	3	3	3	3
Second	2	3	3	2	3
Third	4	2	3	3	2
Fourth	2	3	2	3	3
Fifth	5	4	4	4	5
Sixth	10	7	7	10	10
Total all instars	25	22	22	25	26

During June and July, 1957, close records were kept on the length of the various instars for several groups of larvae, two hundred in each group. The total larvae completing an instar on a particular day was recorded, and when 80 per cent of a group had completed an instar by a certain date, that date was taken as the date of completion of the instar for the group. All larvae were supplied with surplus quantities of food daily. The records of five such groups are given in table 16.

The sixth instar is always the longest in duration during the summer months; however, among overwintering larvae, the middle instars are usually the longest, since the late instars are present toward spring when the weather is warmer.

Inasmuch as the species does significant damage only in the late instars, the total larval development period is of more consequence than the length of time in the various instars. The expected time of the appearance of mature larvae in the field is a factor of considerable importance. During each of the four full broods of 1957, the writer recorded the minimum and maximum periods of larval development on every group of insectary-reared armyworms, and from these data determined the rate of larval development for each brood. The results are

Table 17. Duration of Larval Life of *Pseudaletia unipuncta* in Each of the Four Full Broods in Tennessee, 1957.

Brood number	Period of observations	Number of groups	Mean temperature*	Duration of larval development in days** — Range	Ave.	St. Error
I	Mar. 28-May 20	8	66.5	24-42	34.6	± 2.80
II	June 14-July 15	19	79.2	20-30	23.1	± 0.51
III	July 24-Aug. 29	11	79.2	22-28	25.0	± 0.74
IV	Sept. 2-Nov. 2	12	65.6	22-48	33.7	± 3.11
Totals		50	——	20-48	27.9	± 1.13

*In °F.

**From eclosion to pupation.

presented in table 17. From the data in this table it can be seen that the mimimum period of time required for completion of larval life, twenty days, was observed in early summer and the maximum period, forty-eight days, was observed in fall. The average duration of larval life varied from 23.1 days in early summer to 34.6 days in spring. Comparison of data on duration of larval life and the mean temperature for the period shows the effect of temperature on development. These data might be useful in computing the minimum time required for mature larvae to appear in an area after a flight of moths has been detected. The length of larval life among overwintering specimens was determined in the fall and winter of 1956 and 1957 and that information is given in the section dealing with winter studies.

Annual Broods

The number of annual broods varies with the climate. Knight (1916) reports two broods for New York, while Slingerland (1896) reports at least three for that state. Gibson (1915) gives two as the number of annual broods in eastern Canada. Howard (1896) states that there are two or three broods in the northern states and perhaps six in the South. Knutson (1944) lists two to three for Minnesota. Walkden (1950) gives three for the Central Great Plains and Riley (1883) gives a like number for the Ohio River area, the Great Lakes, and north to central New York. Walton and Packard (1940) list three as the general number of broods without respect to locality.

During each of the past three years, 1955, 1956, and 1957, Tennessee has had five broods of the armyworm. Studies in 1956 indicate that the fifth brood overwinters as partly grown larvae. The dates for the various broods are given in the section dealing with the seasonal cycle.

Outbreaks

Armyworms are present every year and are among the more numerous of the cutworm-like species. When present in only ordinary numbers, they feed singly in grassy areas and attract only little attention. However, under a certain set of conditions not yet fully understood, they become so numerous as to devour all of their breeding area food before they attain full growth. An outbreak results. When this occurs the larvae are forced to move to new areas for food. Unlike many insects under such circumstances, they exhibit a gregarious habit and move *en masse*. This migrating habit gives the species its common name. Such circumstances do not occur often, perhaps not more often than once each ten years or even less in a particular area. The gregarious habit contributes largely to the fact that the species is hardly ever destructive in successive years, for when the larvae become so numerous, they have the serious problem of traveling great distances for food and they expose themselves to wholesale destruction by predators, parasites, and infectious diseases. By this same habit, they likewise expose themselves to easier destruction by the farmer. In Tennessee in 1956 and 1957, a survey revealed 32.3 and 42.5 percent parasitism respectively and in 1957, a virus disease almost completely destroyed the armyworm population in several fields in Monroe, Lincoln, and Franklin counties, and was always a threat to insectary colonies. The effects of natural enemies of the armyworm are more fully discussed in a later section of this work.

A review of past armyworm outbreaks shows the irregular intervals of their occurrence. Even though not validly in our nomenclature until 1810, the armyworm has been known as a serious pest since early colonial times. The outbreak of 1743 over all of the present North Atlantic States is considered to be the first authentic report of widespread armyworm damage in the United States. A severe outbreak occurred in 1861 in the eastern United States, in 1881 in the Midwest, and in 1914 there was a general outbreak in the entire agricultural region east of the Rocky Mountains and north of the Gulf States. Serious outbreaks occurred in Canada in 1861, 1865, 1881, 1896, and 1914.

In recent years localized outbreaks have become more numerous. The recent increase in frequency of localized outbreaks might be due to the greater use of insecticides which kill off large numbers of parasites which normally hold the species in check.

Other Noctuid Larvae with the Armyworm Habit

Certain species of noctuid larvae, other than *P. unipuncta,* sometimes exhibit the armyworm habit of gregarious dispersal, and owing to this habit have been called armyworms. The true armyworm may be distinguished from these others by a combination of the general description given on page 273 by the fact that it usually is found feeding on grasses, and by the time of its appearance in a given area. Crumb (1927) described and keyed all species of noctuids known to assume the armyworm habit. A summary of information on the armyworm species, taken from Crumb's article, is given in table 18. The reader is referred to the original article for detailed descriptions and a systematic key to the various species.

The species most likely to be confused with *Pseudaletia unipuncta* in Tennessee are *Leucania phragmatidicola* and *L. pseudargyria*. *Laphygma frugiperda,* the fall armyworm, might be confused with the true armyworm, not so much for its morphological resemblance as for its frequent appearance in armyworm populations. The writer has prepared a key to separate these four species, since the former three are likely to be confused even by trained workers, and the fall armyworm is added because of its occasional appearance along with the true army-

Table 18. The Species of Noctuid Larvae Exhibiting the Armyworm Habit[1]

Species	Common name	Food plants	Distribution
Chorizagrotis auxillaris Grote	Army cutworm	General	West of Miss. River
Feltia gladaria Morrison	Clay-backed cutworm	Field and garden crops	East of Rocky Mountains
Feltia ducens Walker	Dingy cutworm	Field and garden crops	Northern U. S. and Canada for entire longitude
Pseudaletia unipuncta Haworth	Armyworm	Primarily grasses	East of Rocky Mountains
Leucania phragmatidicola Guen.	Yellow armyworm	Primarily grasses	East of Rocky Mountains
Leucania pseudargyria Guen.	Brown armyworm	Primarily grasses	East of Rockies, more northern
Neleucania albidinea Huebner	Wheat-headed armyworm	Primarily grasses	North of latitude of Ohio River. east of Rockies, also in Ky., Ariz., N. M., and Texas
Agrotis c-nigrum Linnaeus	Spotted cutworm	Field and garden crops	Northern U. S., including Tenn.
Peridroma margaritosa Haworth	Variegated cutworm	Field and garden crops	Entire U. S.
Laphygma frugiperda Smith & Abbot	Fall armyworm	Cereals and grasses, but will attack many others	U. S. west to Nebr., Kans., Tex., and N. M.
Prodenia eridania Cramer	Semitropical armyworm	Field and garden crops	Southern U. S. north to Tenn.
Prodenia ornithogalli Guen.	Yellow-striped armyworm	Field and garden crops	Common only in South, but occurs from N. Y. to Fla. & westward to Minn., Nebr., N. M., Ariz., & Calif.

[1] Compiled from Crumb (1927)

worm in late season. Terminology used in this key conforms to that of figures 9, 10, and 11.

Key to the Larvae of Four Noctuid Species Likely to be Taken for the True Armyworm in Tennessee

1. Skin pavement granulose; each mandible with five distinct teeth; no dark longitudinal stripe on the abdomen through setigerous tubercle II ____ *Laphygma frugiperda*
   Skin smooth; each mandible with but two obscure teeth; with a dark longitudinal stripe on the abdomen through setigerous tubercle II___ 2
2. With a pale longitudinal stripe between setigerous tubercles I and II; spiracles entirely black; setigerous tubercles II on abdominal segment 8 further apart than tubercles I _______________ *Pseudaletia unipuncta*

With not more than a pale line between setigerous tubercles I and II; spiracles yellowish or gray with black rim; setigerous tubercles II on abdominal segment 8 not further apart than tubercles I 3

2. Spiracular area strongly infuscated or black, much darker than supraspiracular area; spiracles pale yellowish, with black rims .... *Leucania phragmatidicola*

Spiracular area but slightly infuscated or black, but little darker than supraspiracular area; spiracles yellowish to dark gray with black rims .... *Leucania pseudargyria*

THE PUPA

General Description (figure 4)

The pupa of *Pseudaletia unipuncta* is a typical noctuid pupa. Both sexes measure from 13 to 17 mm., and average about 14.5

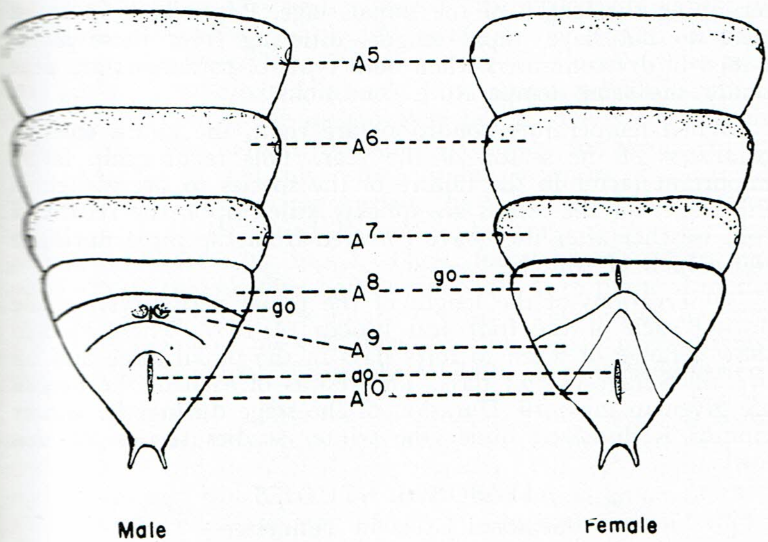

Fig. 12. Terminal segments of the male and female pupa of *Pseudaletia unipuncta* to show sex differences. A^5 to A^{10}-abdominal segments 5 to 10; ao-anus; go-gonopore.

mm. in length, and from 5.0 to 6.0 mm. broad. There are two stiff, converging, black thorns (cremasters) at the anal end, each with a fine curled hook. The color is a light amber at pupation, but darkens to a shiny mahogany brown with age. Figure 12 shows the sexual differences of the male and female pupa.

Place of Pupation

Pupation normally occurs in the soil to a depth of an inch or less depending upon texture of the soil and presence or absence of cracks suitable for larval burrowing prior to pupation. Pupae in the field are normally found beneath dead foliage, clods of dirt, or cracks in the soil. In field experiments and observations the writer has never observed the pupa to be exposed on the surface of the ground. In most cases, the pupa is contained within a little earthen pocket formed around the slightly spun silken case made by the prepupa. However, this pocket is not necessary since successful pupation will occur even on the floor of an open rearing jar where no soil or debris is available.

Duration of the Pupal Stage

Temperature greatly affects the length of the pupal stage of the armyworm as it does the length of egg and larval stages. The humidity does not appear to be an important factor in determining the length of the pupal stage. Pupae kept in moist sand do not have pupal lengths differing from those maintained in dry containers when both types of containers are kept under the same temperature conditions.

When temperature conditions are right, the moths emerge, regardless of the season of the year. This relationship is an important factor in the failure of the species to overwinter in this stage, for the moths are quickly killed upon the return of cold weather after they have emerged from the pupa during a warm spell of winter.

Observations of the length of the pupal period were made during each of the four full broods of 1957. These records show a range of seven to forty days in the pupal stage and an overall average of 15.1 days. The results of each of the broods are given in table 19. Duration of the stage during the winter months is discussed under the winter studies section of this work.

SEASONAL STUDIES

Seasonal Cycle in Tennessee

During the course of this study the writer has been able to observe the armyworm for two complete seasons. By com-

Table 19. Duration of Pupal Life of *Pseudaletia unipuncta* in Each of the Four Full Broods in Tennessee, 1957

Brood number	Period of observations	Number of groups	Duration of pupal life in days		
			Range	Ave.	St. Error
I	May 14-June 10	10	10-17	13.6	± 0.37
II	July 5-July 27	11	7-13	9.8	± 0.44
III	Aug. 14-Sept. 12	15	8-14	11.3	± 0.42
IV	Sept. 28-Nov. 16	8	24-40	31.6	± 0.74
Totals		44	7-40	15.1	± 1.76

bining information obtained from direct field observations, insectary rearings under near natural conditions, and light trap data, the seasonal cycle of the species in the state has been elucidated.

In early March, 1956, overwintering forms began to produce a few adults, but from a population standpoint the active spring flight period of the first 1956 moths began the first week in April, reached its peak the middle of April, and continued through the first week of May. This flight of moths deposited the eggs which hatched into the first 1956 brood of armyworms. In mid-May, a survey by the writer of several East Tennessee counties from Knox to Johnson, revealed the quite general presence of immature armyworm larvae in grain fields throughout the area. These larvae reached the sixth and final instar by the third week of May and appeared in destructive numbers of outbreak proportions on several farms in the survey area, as well as in the Sweetwater Valley of Monroe County. The general outbreak culminated in early June producing adults which were the parents of the second 1956 brood. The second flight reached its peak in mid-June and accounted for second-brood mature larvae in mid-July, which produced adults of the third brood in late July. By late August, the third brood larvae were mature and adults issued in mid-September, which were the parents of the fourth brood. These fourth-brood larvae matured toward mid-October and produced the fifth flight of moths in early November. These moths deposited eggs which hatched and developed into the fifth brood worms which overwintered and produced the first 1957 flight of moths the following spring.

The first 1957 moths issued from pupated overwintering larvae, from early March to early May, but reached their peak in mid-April as did their 1956 counterparts. The 1957 moths deposited the eggs which gave rise to the first brood larvae of 1957 which matured in late May and from which the second flight of moths resulted in early June. These moths produced the second brood larvae which matured in early July and which produced the third flight of moths in late July and early August. The larvae from this flight, the third brood, matured in late August and produced the fourth flight of moths in mid-September. The fourth brood larvae resulting from this flight matured in mid-October and produced the fifth flight moths in early November. These moths deposited eggs which hatched to produce the fifth brood larvae which are destined to overwinter and produce the first 1958 flight of armyworm moths.

By comparing the account of the 1956 and 1957 seasonal cycles, the reader can see the close correlation of the cycle in the state for those two years. The cycle for the 1956 season is represented in figure 13.

Winter Studies, 1956-57

A cloak of confusion has hung over the winter activities of the armyworm because most studies have dealt with the species only during outbreak periods of major outbreak years. Adding to the confusion is the fall armyworm, *Laphygma frugiperda,* which is preserved as a permanent resident only in the warmer parts of the South, passing the winter in the United

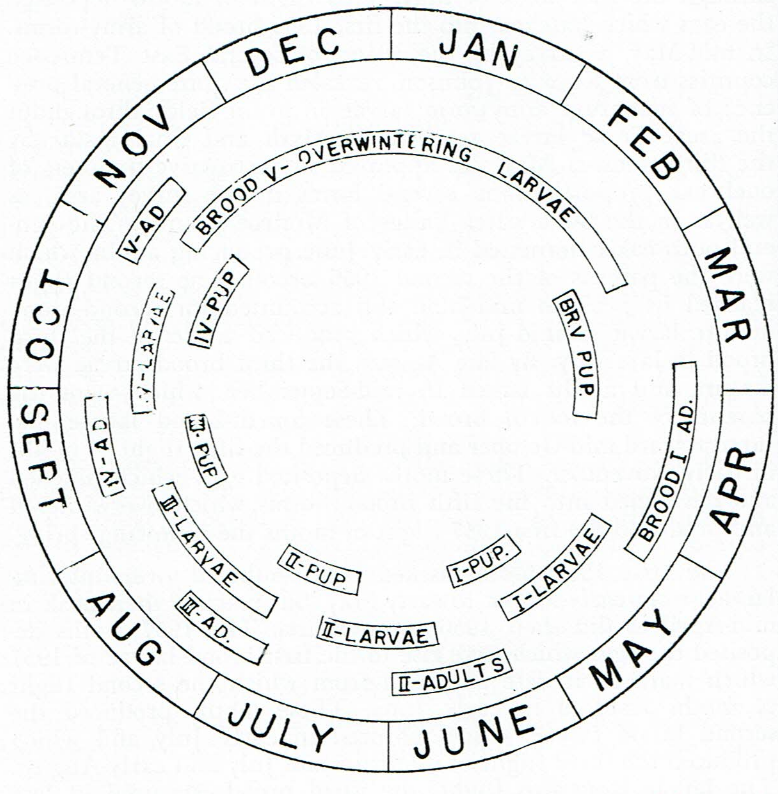

Fig. 13. Graphic representation of the seasonal cycle of *Pseudaletia unipuncta* in Tennessee.

States in that region included in the tropical life zone. This insect becomes redistributed each year by migrations of the moths over most of the austral region (Luginbill, 1928). Because of the similarity of the fall armyworm to the true armyworm, *P. unipuncta,* in structure, gregariousness, and common name, this migratory habit has often been attributed to the true armyworm in explanation of its sudden appearance in the spring. To help clarify this situation and to elucidate the real overwintering status of the true armyworm in temperate regions, a three-phase study of the winter habits of the species was conducted in the fall and winter of 1956-57, the methods and results of which are herewith presented.

Winter Study Number One

This phase of the winter study was conducted to determine the ability of the armyworm to overwinter in Tennessee under natural conditions. On October 18, 1956, 40 sixth-instar armyworm larvae from the insectary colony were released, 20 each, in two cylindrical screen wire baskets, 18 inches tall and 12 inches in diameter, open at one end. These containers had previously been partly filled to a depth of several inches with soil and grass removed from a likely looking armyworm habitat. Each container was then placed in a hole from which the soil had been removed. A portable plastic screen cage, 6 feet by 6 feet by 6 feet, open at the bottom and with a zipper opening on one side, was placed over the area where the baskets were located. The frame of the cage was of one-half inch iron pipe, the four corners driven into the ground and packed with soil in a fold of the screen. Larvae of instars other than the sixth developed in the insectary colony in late December, 1956, and by January 7, 1957, larvae of the first five instars had been similarly released. Twenty specimens each of the first, second, third, and fourth larval instars were released into clay flower pots of 4-, 5-, 6-, and 8-inch top diameters respectively. Fifth instar larvae were released into wire baskets of the same dimensions as the one previously described for sixth-instar specimens. All containers were manipulated as already described. Observations of the contents of each container were made at irregular intervals throughout the fall and winter, with daily observations as spring neared. Soil temperatures were taken at frequent intervals, for the most part daily, throughout the period of study (table 20). As pupation approached, cheese-cloth was tied around the top of containers to prevent the escape of emerging adults. On March 25, 1957, the specimens, after having obviously withstood the winter, were removed from each container to individual metal salve boxes and kept at outside temperatures until development was completed.

With one exception, all surviving sixth instar larvae, released on October 17, 1956, had pupated by October 29, 1956, and adults had emerged in December, 1956. This coincided with the presence of adults in the greenhouse light trap during December, 1956, from which were obtained colony "worms" which had been released into baskets in the first week of January, 1957. The one exception among the sixth instar "worms" released on October 17, 1956, was a specimen which was still a sixth instar larva on February 21, 1957, and which pupated on