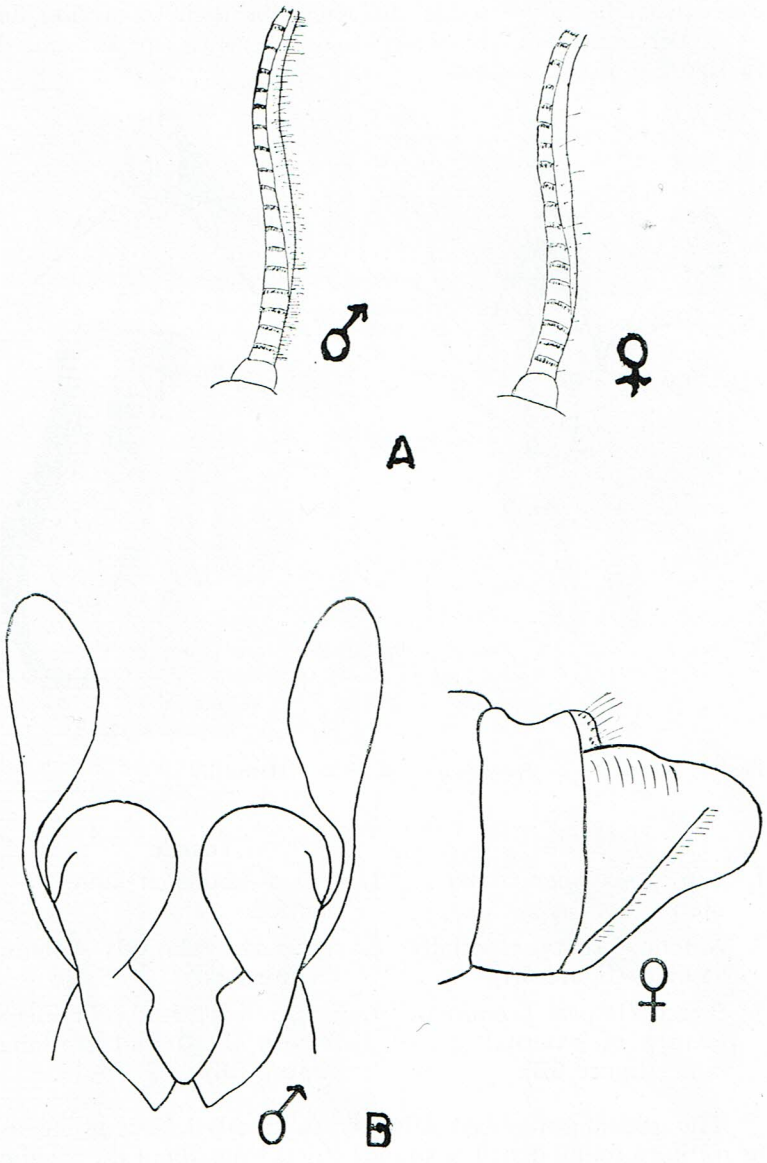

Fig. 6. Comparison of male and female sexual characteristics: A, male and female antennae; B, male (ventral view) and female (lateral view) of genitalia.

to the terminal segments. The female genitalia may best be seen from a lateral view, the male from a ventral view.

Daily Activities of the Moth

The armyworm moth normally remains quiescent during the greater part of a day, becoming active only after sunset. At dusk the day's activity (*i. e.,* feeding, mating, or ovipositing) of a particular moth is begun, and continues until the impulse is satisfied. The writer has never observed a moth in flight during the bright part of the day either in nature or captivity unless the moth was disturbed, but he has observed a number of moths in active flight during twilight hours and after dark in the field and in captivity. Mating and oviposition have been seen at dusk and after dark and on some occasions oviposition, but not mating, as had been noted during daylight hours on overcast days. Feeding may be observed at any hour among confined moths.

Food of the Moth

The armyworm moth is not injurious in its feeding and consequently little work has been done concerning its food habits. Forbes (1905) reports that the moth is fond of sweets and may be captured in large numbers at night by using sugary substances as bait. Riley (1883) states that the moth undoubtedly feeds upon the nectar of various flowers and reports that it has been taken in the evening from the blossoms of clover, apple, honeysuckle, and yucca. Walkden (1937) reports that in Kansas between 1921 and 1931, the armyworm moth was one of only five species caught for the eleven consecutive years of a bait trap operation in which a bait of crushed banana and a 10 percent solution of molasses in water was used. Knight (1916) reported moths feeding on mashed and decaying apples, sipping the nectar of catnip, and observed one feeding on a ripe apple hanging on a tree. The writer fed moths on a weak sugar solution approximating two per cent. It is probable that the moths in nature prefer the nectar of flowers, but will feed on any sweet exudation available.

Attraction to Light

The armyworm adult, like other noctuid moths, is strongly attracted to light. For this reason light traps have been employed to supplement field and insectary studies.

The early theory was that lepidopterous insects taken at light were practically all males and that the relatively few females taken had previously oviposited. If this were true, the use of light traps would be of little value as an instrument for studying habits of the moth.

Turner (1918 and 1920), Dirks (1937), Knutson (1944), and Pfrimmer (1957) have all conducted studies which contribute information on the sex-ratio of light-collected armyworm moths.

In addition to the sex-ratio, Turner and Dirks gave the percentage of females which were found to be gravid. Table 1 is a compilation of data from the above sources. Chi-square tests for differences from a 1:1 sex-ratio showed a significant difference in the sexes in favor of the males in the work of Turner (1918), Dirks (1937), and Knutsen (1944). A total of 976, 947, and 949 moths sexed by the above workers respectively, showed 43.5, 45.0, and 39.0 per cent females respectively. Turner (1920) sexed

Table 1. Some records of Light Trap Catches of Various Workers Showing Ratio of Female and Gravid Female Armyworm Moths.

Source of data	Dates	Location of traps	No. moths	No. females	% females	Per cent gravid	Chi-square	Probability
Turner (1918)	1916	Md.	976	424	43.5	80.0	16.8	<.0001
Turner (1920)	1918	Md.	55	21	38.0	62.0	3.07	.08
Dirks (1937)	1931-34	Me.	947	428	45.0	45.0	8.75	.003
Knutson (1944)	1927-40	Minn.	949	371	39.0	—	45.2	<.0001
Pfrimmer (1957)	1955	La.	2119[1]	1080	51.0	—	0.79	.80
			4328[2]	2422	56.0	—	60.0	<.0001
			3069[3]	1688	55.0	—	30.7	<.0001
	1956	La.	283[1]	181	64.0	—	17.8	<.0001
			1279[2]	959	75.0	—	329.2	<.0001
			1275[3]	1033	81.0	—	489.5	<.0001

[1]Mercury vapor; [2]Black light; [3]BLB.

a total of fifty-five moths, twenty-one (38.0 per cent) were females. Although a Chi-square test to determine difference from a 1:1 ratio was not significant, it must be noted from the data of Table 1 that the percentage of females in this case was the lowest of the several groups represented in the table. The fact of no significant difference is undoubtedly due to the small sample, since higher percentages of females in other groups showed a significant difference by the same statistical test. Pfrimmer (1957), using more modern light sources, collected more females than males from each of three traps in 1955 and 1956. The difference was significant in each case except for the mercury-vapor trap operated in 1955 (see table 1).

During the 1957 season the writer sexed 12,054 armyworm moths which had been caught at black light in Tennessee. Of these 5,785, or 47.9 per cent, were females. The chi-square test

for differences from a 1:1 ratio for all moths sexed showed a significantly higher number of males for the season. However, as can be seen from the data of table 2, the percentage of females was higher than that of males in the first two broods and continued to regress with time until the last brood when the percentage of females increased from the previous brood.

From the data in both tables 1 and 2, it can be seen that a relatively high percentage of light-collected female armyworm

Table 2. Records of Light Trap Catches of Armyworm Moths in Tennessee, 1957, Showing Sex Ratio and Percentage of Gravid Moths.

Flight number	Flight period	Total sexed	Number males	Number females	Per cent females	Per cent gravid
I	March 11-May 20	1854	566	1288	69.5	*63.0
II	June 3-June 24	1657	774	883	53.3	—
III	July 15-Aug. 12	4958	2828	2130	42.9	—
IV	Aug. 26-Sept. 16	2207	1343	864	39.1	—
V	Oct. 14 Nov. 11	1378	758	620	44.9	—
Totals		12,054	6269	5785	47.9	—

Chi-Square for totals = 19.4; probability = <.0001

* Represents 17 of 27 moths caught alive from which fertile eggs were obtained. Routinely caught specimens were sent to Louisiana State University for special studies.

moths is gravid, indicating that they had not deposited all of their eggs before being caught.

To determine whether the writers' light-collected samples of moths showed a significantly higher percentage of males because of their greater numbers in the population or whether this difference might be due to other factors not associated with the actual sex-ratio, insectary-reared armyworm moths from the various colony groups were sexed during 1957. A total of 1,478 moths sexed showed 711, or 48.1 per cent, to be females, a figure not significantly different from the number of males. These data are given in table 3. On the basis of these tests, it appears that the population approaches a 1:1 sex-ratio, but that factors are in operation which result in a significantly larger number of one sex being caught in light traps. The type of light and season appear to play a part.

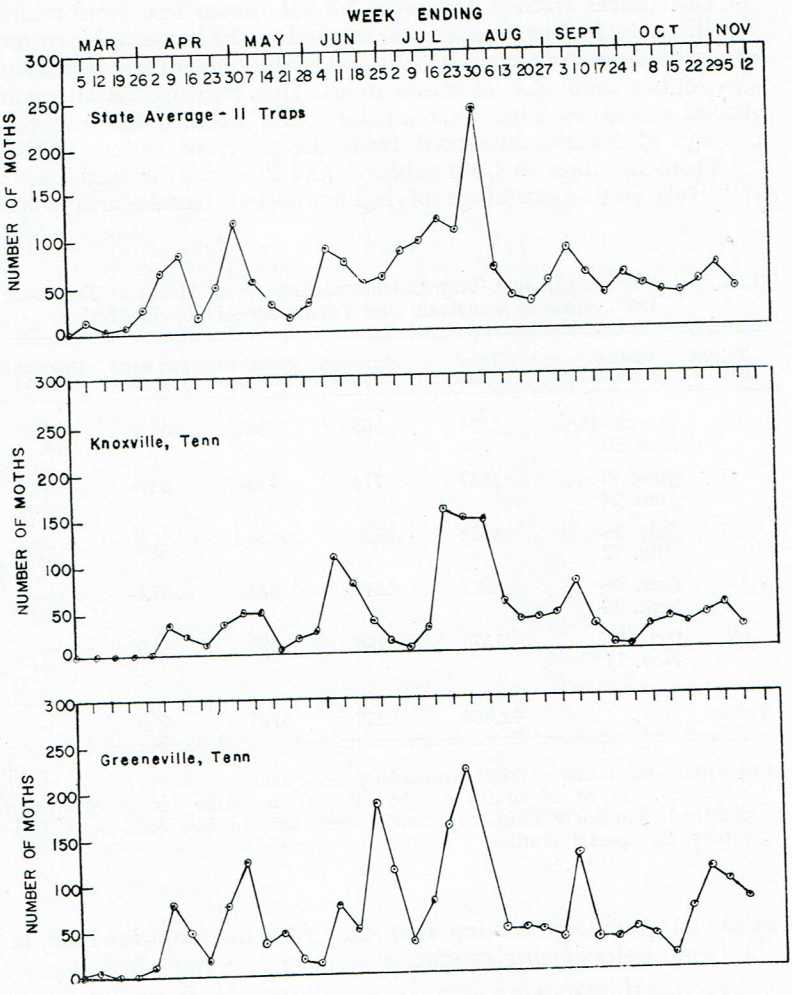

Fig. 7. Graphic representation of the 1956 seasonal flight pattern of the armyworm moth in Tennessee.

The data obtained from light traps were used to supplement seasonal history studies in the insectary and in the field. The trap descriptions and their locations have been given previously in the materials and methods section of this work. A summary of catches for the 1956 and 1957 seasons is given in tables 4 and 5 respectively. Figure 7 is a graphic illustration showing the 1956 flight pattern based on light trap records for the state as a whole and for two East Tennessee traps in areas where most of the field observations were made.

Since the first generation eggs must be deposited by the first flight of moths in spring and since the first brood is the damaging one in Tennessee, it is the opinion of the writer that light trap data might be used successfully to time expected dates of armyworm damage. By utilizing life history data and calculating the earliest possible date for the appearance of mature worms from the time of the peak of the spring flight in a general climatic area, the development of an effective warning system is possible. As has already been pointed out, light trap records are further useful in working out the number of annual broods in a given area. Such records must be used only to supplement carefully planned insectary rearings and field observations since there is a tendency for much overlap in late-season broods.

The Seasonal Flights

There are five annual flights of the armyworm moth in Tennessee, producing four complete broods and a partial fifth brood which overwinters as partially grown larvae. These flights occurred in 1956 as follows:

Flight I — March 3 to May 7
Flight II — June 8 to July 1
Flight III — July 23 to August 13
Flight IV — September 1 to September 30
Flight V — October 30 to November 15

The flights can be seen in the peaks of the line graphs of figure 7 showing some light trap records for 1956. The flight records as indicated by light traps compared favorably with records from the insectary colony and from field observations.

Adult Emergence

The armyworm pupates in the soil to a depth rarely exceeding two inches, more often at an inch or less. The pupal cell, formed from a small amount of silk spun by the prepupa, is oval in shape and incompletely formed. The cell usually forms a little earthen pocket in loose soil or in cracks of harder soil. After breaking through the pupal coverings, the moth pushes its way to the surface and hangs on debris or foliage until its wings have stretched and its body has hardened, a process which usually requires about three hours.

Experiments were conducted to determine if one sex emerged earlier than the other. There was some indication that of specimens pupating on the same day, the females began emerging slightly earlier than the males, but this time advantage of the females in eleven such groups was never greater than one day. However, in no case did male emergence begin earlier than did female emergence.

Mating

Mating usually occurs in from one to three days after emergence of the adult. Apparently only one mating is required to fertilize the entire life production of eggs of a female. One female, isolated from males after mating, depositing 1759 eggs, all of which were fertile. The mating position is end to end. The moths occasionally become stuck together in the mating process and cannot be separated. The frequency of this occurrence is greatest during hot, dry weather.

Experiments were conducted to determine whether polygamy occurs among male armyworm moths. Two containers were set up with two females and one male in each; three with three females and one male; and six with four females and one male. In no case was there evidence of polygamy. Fertile eggs were obtained from only one female in any of the combinations.

Table 3. Sex Ratio of Insectary-Reared Armyworm Moths, *Pseudaletia unipuncta,* 1957.

Flight number	Flight period	Males		Females	
		Number	Per cent	Number	Per cent
I	March 11-May 20	36	43.9	46	56.1
II	June 3	195	50.5	191	49.5
III	June 24 July 15-Aug. 12	287	48.2	206	51.8
IV	Aug. 26-Sept. 16	156	52.4	142	47.6
V	Oct. 20-Nov. 11	93	42.5	126	57.5
Totals		767	51.9	711	48.1

Chi-square for totals = 2.12; probability = 0.15

Infertile eggs were obtained from more than one female in several cases, indicating that oviposition without fertilization occurs in the species.

Oviposition Without Fertilization

Fifteen virgin females were isolated for further observations on oviposition without fertilization. Only three of the fifteen moths deposited eggs, one of these moths deposited fifty and another only four. These observations indicate that oviposition without fertilization is infrequent and the haphazard arrangement of the eggs indicates that the deposition of infertile eggs might require greater effort than the deposition of fertile eggs. The same situation has been reported in the case of the fall armyworm, *Laphygma frugiperda,* by Luginbill (1928).

Table 4. Weekly Record of the Number of Armyworm Moths Caught in Light Traps During 1950 in Tennessee.

Date Week Ending		Location of Traps by Counties											
		Shelby	Madison	Lawrence	Maury	Robert-son	Cumber-land	Knox	Greene	Blount	Marion	Johnson	Total
March	5	0	1	—	1	0	0	0	0	—	—	—	2
	12	44	24	3	8	1	0	0	4	—	—	—	84
	19	23	0	4	3	1	1	0	—	—	—	—	32
	26	14	1	—	7	1	2	0	—	—	—	—	25
April	2	62	52	25	47	6	1	2	9	—	—	—	204
	9	243	34	22	53	30	6	35	76	—	—	—	419
	16	386	21	22	120	32	6	21	44	—	—	—	652
	23	67	8	5	21	0	2	11	17	—	—	—	131
	30	51	0	10	140	26	—	36	74	—	—	—	337
May	7	225	126	—	119	66	—	45	123	134	—	—	838
	14	76	—	—	18	0	—	—	31	69	86	95	375
	21	120	64	5	8	12	6	5	43	11	21	27	322
	28	—	15	—	8	5	2	18	16	33	4	11	112
June	4	—	48	0	0	160	5	22	10	12	—	4	261
	11	—	—	—	136	96	6	104	72	34	—	168	616
	18	10	—	—	80	120	16	78	48	—	—	144	496
	25	6	—	40	76	45	8	33	182	48	—	11	449
July	2	—	8	40	12	152	8	12	112	28	—	128	500
	9	14	64	54	32	76	32	6	32	24	—	478	812
	16	—	22	20	88	56	35	22	72	32	—	487	834
	23	42	48	32	105	87	118	154	158	88	—	294	1126
	30	40	—	16	42	44	78	148	216	216	—	102	902
August	6	—	294	156	108	380	377	144	285	156	—	—	1900
	13	51	144	68	42	52	44	58	48	100	—	34	641
	20	57	40	28	34	44	18	32	44	28	—	—	295
	27	0	—	28	18	36	13	33	44	38	—	26	236
September	3	39	113	16	18	94	32	40	32	8	—	98	490
	10	75	27	36	75	120	18	71	125	0	—	263	810
	17	—	79	26	6	177	82	26	32	6	7	109	550
	24	42	—	4	20	20	35	7	31	—	—	107	266
October	1	81	20	12	20	12	18	3	42	—	—	275	483
	8	—	32	—	4	64	28	26	36	4	—	142	336
	15	6	18	—	—	20	25	32	12	5	—	141	259
	22	36	6	—	34	15	3	28	65	16	6	104	313
	29	10	26	11	—	20	12	38	108	20	—	176	421
November	5	38	31	—	—	84	—	49	95	27	—	107	431
	12	—	2	—	16	64	38	21	71	9	—	92	313

— No collection

Table 5. Weekly Record of the Number of Armyworm Moths Caught in Light Traps During 1957 in Tennessee.

Date Week Ending		Location of Traps by Counties											
		Lauderdale	Madison	Lawrence	Maury	Robertson	Cumberland	Knox	Greene	Blount	Monroe	Johnson	Total
March	11	—	11	—	10	0	3	—	—	—	57	—	81
	18	39	17	42	19	1	31	5	18	1	43	3	219
	25	211	32	25	58	5	10	13	9	1	140	5	509
April	1	159	93	47	35	2	4	8	14	7	107	2	478
	8	323	170	36	114	6	6	17	14	30	175	41	932
	15	1	4	10	65	5	3	0	4	0	6	3	101
	22	54	—	—	436	22	28	—	75	24	1018	30	1687
	29	—	540	53	320	24	34	186	233	25	557	758	2730
May	6	27	154	38	181	16	13	86	95	9	97	313	1029
	13	—	20	—	18	19	22	36	14	—	23	34	186
	20	—	46	—	2	2	2	2	6	1	4	30	95
	27	208	3200	90	—	50	2	10	8	—	20	6	3594
June	3	64	784	34	30	12	9	22	12	1	3	—	971
	10	84	63	9	26	26	13	43	48	4	72	618	1006
	17	—	12	—	24	10	6	18	12	—	2	44	128
	24	—	21	8	34	12	3	42	32	—	—	85	237
July	1	32	210	10	8	84	8	29	12	2	8	888	1291
	8	—	—	12	32	24	16	132	40	14	—	—	270
	15	2	7	—	9	2	2	35	4	24	7	44	136
	22	48	56	12	12	104	—	120	208	24	3	246	833
	29	—	54	40	24	238	6	346	220	33	—	768	1729
August	5	220	162	108	76	588	16	338	332	—	152	—	1992
	12	80	140	—	—	36	17	114	50	16	100	84	637
	19	55	—	40	—	144	48	128	132	32	156	180	915
	26	—	217	24	—	28	44	96	48	34	200	256	947
September	2	35	56	32	4	32	6	76	64	—	89	64	458
	9	64	192	24	13	4	26	60	8	13	32	48	484
	16	8	28	37	14	22	10	84	26	12	—	84	325
	23	—	56	—	92	48	—	32	60	16	—	324	628
	30	—	120	8	24	40	32	36	32	6	—	196	494
October	7	—	40	—	20	24	32	42	8	16	—	568	750
	14	—	8	—	12	10	18	40	8	8	—	27	131
	21	—	132	—	—	40	—	40	38	8	—	92	350
	28	—	172	—	31	9	—	31	—	13	—	75	331
November	4	—	122	—	100	100	—	36	—	17	—	5	380
	11	—	148	—	—	11	—	7	—	6	—	14	186

No collection

Time and Place of Oviposition

The writer has not observed the oviposition act of the moth in the field, but he has observed it at numerous times among caged moths. Riley (1876) once offered a reward of twenty thousand dollars to anyone finding the eggs of the species in the field; the fact that there were no takers testifies to the difficulty of such a discovery. This is due to the moth's habit of concealing the eggs in tight places. Despite shortcomings in actual field observations of the eggs, much knowledge on the preferred oviposition sites of the moth has been gained through breeding cage work, field observations of freshly hatched larvae, and in the writings of some who have succeeded in finding the eggs in nature.

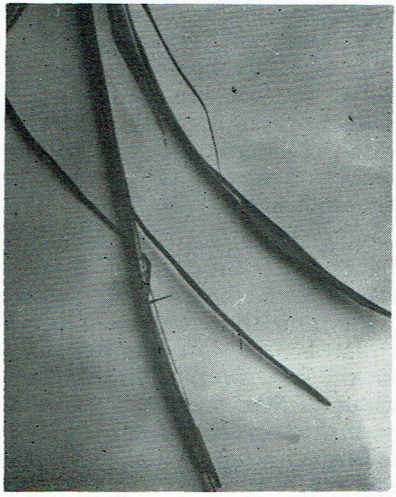

Fig. 8. Egg masses of *Pseudaletia unipuncta* showing manner of concealment.

From all evidence available, it seems that the moth oviposits most frequently in tight places as provided by the narrow space between the sheath and blade of growing grasses or the same in cut, dried straw or corn stalks. In experiments in which the moths were given a choice, they showed a decided preference for the latter. Also the moth will deposit her eggs readily in a narrow, tender grass blade which has a tendency to fold lengthwise and stick (figure 8).

Subsequent to his 1876 report, Riley (1883) stated that there was satisfactory proof that early in the season the moths oviposited by preference in the cut straw of haystacks, and even in old fodder shocks of corn stalks. He reported that old bits

of corn stalk from various localities had repeatedly been found with armyworm eggs thrust under the outer sheath. He also reported that year-old stalks of grass likewise contained eggs.

Experiments by the writer showed more frequent oviposition on straw than on grass. Further experiments showed more frequent oviposition on folded paper strips than on fresh, succulent, potted grass plants. The strips more nearly resemble straw than grass in physical properties. Despite this apparent preference for stubble, the space between the sheath and blade of fresh grasses is readily utilized as an oviposition site and although not favored, is probably used more than stubble because of its greater availability.

The fact that folded paper strips as described in the materials and methods section are superior oviposition sites is evidenced by the data obtained from experiments utilizing various grasses and the paper strips. The tests were run for three days during the peak of the second brood oviposition period. Paper strips and six kinds of grasses were used (see table 6). The grasses were planted in individual clay flower pots and the paper was inserted into the dirt of the flower pot. Four replications were used on each of the three days. The results are given in table 6.

In the absence of good oviposition sites, the moth will deposit her eggs in available places, but almost always in a tight place. Eggs were frequently found beneath the paper covering on the floor of rearing jars and in crumpled paper towels placed in cages for hiding places. The most unusual site which the writer observed was on the narrow portion of the wing of a luna moth, when both specimens were caught in a live trap. It is interesting to note that the site in this case was surprisingly similar to a grass blade.

Oviposition normally begins after light begins to fade in late afternoon and seemingly continues until all eggs ready for deposition on a given day have been deposited. Oviposition is completed during the early hours of the night unless the act is delayed by excessive artificial light. Oviposition has been observed in some instances in daylight, but only on heavily clouded days.

The writer has records of oviposition at temperature readings as low as 38° F. and as high as 95° F.

Manner of Oviposition

The method of oviposition in the species was observed by allowing the moth to oviposit in a small slit between two microscope slides. The slides were prepared by placing a piece of match-box cardboard at each end between the slides which were held together with cellophane tape, thus leaving a slight space between the slides.

Table 6. Number of Eggs Deposited by Females of *P. unipuncta* on Various Oviposition Media, 1957.

Date	Wheat	Oats	Barley	Sudan Grass	Dallis Grass	Johnson Grass	Folded Paper Strips
July 13	0	0	19	0	40	78	2040
July 14	178	24	50	0	106	88	857
July 15	32	0	88	15	35	0	425
Total	210	24	157	15	181	166	3322

A female moth ready for oviposition shows a slightly nervous behavior. Typically her wings vibrate at a quick, jerky pace, and she crawls or flutters about with her abdomen bent forward and downward with ovipositor extended. In this position she crawls nervously forward moving her abdomen from side to side in an arc with the ovipositor in contact with the substrate. When she finds a suitable oviposition site such as the glass slides described above, folded paper, or under more natural conditions, straw or a grass blade, she thrusts her ovipositor far forward in the slit and begins to deposit her eggs singly. In a grass blade, her ovipositor serves to form a crease and a sticky secretion from her colleterial glands seals the blade. The first egg is deposited at the greatest distance inward to which her ovipositor will reach. The ovipositor is then moved outward with each successive egg deposition until the edge is reached. This continues until the female is disturbed, until she reaches an obstruction, or until all of her mature eggs have been deposited.

Rate of Oviposition

On the evening of May 23, 1957, in Knoxville, six female moths, isolated in rearing jars, were observed in the act of oviposition. The time that oviposition commenced was recorded for each female and at the end of a particular period of oviposition, the paper was removed, the time interval written on the paper, and the old paper was replaced by a fresh one. At the end of all oviposition the totals were recorded. The results are in table 7.

Table 7. Rates of Oviposition of Six Female Moths, *P. unipuncta*, May 23, 1957.

Female Number	Time of Oviposition	Duration of Oviposition	Number of Eggs Deposited	Rate (No. Min.)
1	6:10-6:40 P.M.	30 Min.	210	7.0
2	6:12-6:25 P.M.	13 Min.	45	
	6:27-6:40 P.M.	13 Min.	50	3.8
3	6:23-6:40 P.M.	17 Min.	78	4.6
4	6:40-7:03 P.M.	23 Min.	110	4.8
5	6:40-6:55 P.M.	15 Min.	75	
	6:57-7:10 P.M.	13 Min.	48	4.4
6	6:40-6:55 P.M.	15 Min.	87	5.8
Average of 8 egg masses		17.5 Min.	88	5.03

From the data in this table, it can be seen that the moths deposited their eggs in masses at a rate which ranged from 3.8 to 7 eggs per minute and averaged about 5 eggs per minute. In the case of these six moths, oviposition began at 6:10 p.m. and was completed at 7:10 p.m. The time averaged 17.5 minutes for each of the egg masses and 23 minutes for each moth, two moths each depositing two separate masses. From the average number of eggs obtained daily from numerous females, it would seem that these records closely approximate the daily egg laying habits of the species. However, on occasion, a moth will deposit several egg masses of considerable size in one day. It must be noted that the day of these observations was heavily overcast and much darker at 6:00 p.m. than is usual for the time of year in Tennessee.

Egg Masses

As explained in the preceding section, the armyworm moth deposits her eggs in masses. The mass is usually composed of several rows of eggs covered with a white adhesive fluid which fastens them together and draws the sides of the substrate together so that nothing but a narrow glistening streak is visible. The moth seldom deposits all of her eggs in one mass, but may deposit several masses in a given oviposition period. The lifetime egg laying records of several moths are given in table 8 to show the relationship of the egg mass to the over-all oviposition pattern. From the data given in the table, it can be seen that the moth has a preoviposition period of several days after emergence (see also table 12). Once oviposition begins it continues for a period of several days (see table 10) with from one to several masses of eggs being deposited each day. After deposition of all eggs there is usually a postoviposition period of a few days before death of the moth. Table 9 gives the extremes and averages of the number of egg masses and the number of eggs per mass which were deposited by females in confinement during the 1957 season. The data of table 9 shows that the armyworm moth deposited from one to sixteen egg masses during life with an average of 4.9 masses. The number of eggs per mass ranged from three to four hundred and averaged 108.4. Typical egg masses are shown in figure 4.

Duration of Oviposition and Egg Production

Once oviposition has begun by a moth it normally continues for a week or longer before the female has deposited all of her eggs. The extremes and average duration of the oviposition period for the five 1957 broods of the armyworm moth are given in table 10.

The fecundity of the armyworm moth has been neglected in the literature and figures that have been recorded are much below those observed by the writer. Riley's (1883) extreme