LARVAL INSTARS AND FEEDING OF THE BLACK CUTWORM, AGROTIS YPSILON ROTT.[1]

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INTRODUCTION

The studies of the black cutworm, *Agrotis ypsilon* Rott., here described, were undertaken because of outbreaks of the insect which occurred in the "overflow land" of the Black River in the neighborhood of Hoxie, Ark., following inundations that affected thousands of acres of cornland in 1927 and 1928. The experimental work was carried on at the field laboratory of the Bureau of Entomology in Webster Groves, Mo.

NUMBER OF GENERATIONS

The investigations indicate that there are three generations annually, the adults emerging early in April or May from pupae formed in the fall. The individuals in groups 28727 and 28730 developed from larvae collected in the field in the Hoxie district in 1928. Numerous adults were obtained in October of that year, and some lived until December, but no eggs were produced by them. Those in group 29033–b were from a female captured May 14, 1929. Those in groups 29111 and 29127 were from group 29033–b. Three definite broods were reared from this stock. None of the adults obtained in these experiments survived the winter.

METHODS

The cages in which the adults were held for oviposition consisted of inverted jelly glasses set in 4-ounce tin boxes, of 2-ounce tin boxes covered by jelly glasses, and of lantern globes with cheesecloth tops and saucer bases.

Eggs were collected daily in the early forenoon, and usually again in the late afternoon, and were kept under frequent observation in closed 2-ounce tin boxes. The newly hatched larvae were caged in 9 by 35 mm culture tubes having tight cotton or cork stoppers. Corn foliage was used for feeding experiments.[3] In the small culture tubes cross sections of corn leaves about one-quarter inch long were used. As the larvae grew and were less likely to be lost, they were placed in 25 by 100 mm shell vials, and when more than half grown were placed in 4-ounce tins. When it seemed apparent that the larvae were

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[2] The writer was assisted by R. C. Lange, assistant scientific aid, and, in the summer of 1929, by James B. Gahan and Dorothy Boyer, in the experimental work described in this paper.

[3] An exception occurred in the night of May 26, when the larvae in group 29033–b were hatching. Each set was given a piece of wheat leaf at 9.10 p. m., which was exchanged for corn foliage by 9.30 a. m. the next day. Micrometer caliper measurements revealed a thickness of 0.09 mm at the edge and 0.11 mm in the blade in both corn and wheat leaf blades, May 27. The quantities eaten were very small and were prorated for each set.

through feeding, sifted soil was added to the tins to permit the larvae to burrow in and form earthen cocoons for pupation.

The partly consumed foliage was removed from the cage once daily and pressed to keep it flat until it could be measured. Rarely, when none had been eaten, the foliage was left another day. In the later instars the supply had to be replenished more than once a day. Each piece of corn leaf blade was cut accurately to a prescribed length and was removed while its outline remained discernible. As the larvae increased in feeding capacity, it was necessary to record the number of pieces given, together with their lengths and widths, as an entire piece might be eaten and thus escape record.

Areas consumed were determined by the use of cross-section paper ruled to hundredths of a square inch. The original contours of pieces of foliage were determined by records and by their remaining edges. By these means the quantity consumed was quickly computed.

Head measurements were made preferably with micrometer calipers adjusted to read 0.01 mm. Measurements made with the aid of the eyepiece of the microscope were less dependable, apparently because of personal error in choosing the plane at which to make the measurement, but this method was used generally until after the second instar. While being measured with the calipers, the larva was held on a moistened camel's-hair brush, when possible, but older larvae were held between the finger and thumb. All measurements were made on the upturn, a procedure which eliminated the error due to the looseness of the caliper screw, as the instrument was set to begin on the upturn at zero.

DESCRIPTION OF SEVENTH AND EIGHTH LARVAL INSTARS

Crumb (*1, p. 55–56*)[4] published descriptions of the first to the sixth instars, apparently having encountered no records of 7-instar or 8-instar larvae. The following descriptions[5] were written from a study of one larva of each of the seventh and eighth instars in life, the specimens being immediately killed and preserved for reference. Ridgway's color key[6] was used for determining the colors recorded.

SEVENTH INSTAR.—Head 3.62 mm broad. Extended body 5.48 mm thick, 50 mm long. Cervical shield olivaceous black with narrow median line pale gull gray, and a pale spot at cephalic margin about one-sixth the width of shield from each side. Frons verona brown; major color on epicranium fuscous black on verona-brown background. Ocelli 1, 2, and 5 translucent, appearing whitish; 6 nearly so; 3 and 4 dark. Median line much interrupted, almost wanting on third thoracic and first abdominal segments, vetiver green, as also most of the limited light color of dorsum. Setal spots Ia and IIa blackish slate, each of the II series spots bordered mesad by spots of olive buff. Venter dark grayish olive. Ground color of anal plate dark olive buff, overlaid in part on each side of median line with deep olive. The encircling zone of setal spots III, IV, and V, and setal spot V, pale olive gray, setal spots III and IV olive gray.

EIGHTH INSTAR.—Head 3.84 mm broad. Body 5 mm thick, about 45 mm long. Neck full, as if nearing a molt. General color dark olive green with pale olive buff at mesal bases of series of II setal spots, with pale gull gray encircling bases of setae III, IV, and V, with V spot itself gleaming white. Head: Frons and region of eye and antenna verona brown; upper and middle epicranial halves and an area low on side brownish olive, the latter an island on the verona-brown area. Ocelli 1, 2, and 5 translucent, appearing whitish, 3, 4, and 6 nearly the color of the

[4] Reference is made by number (italic) to Literature Cited, p. 530.

[5] The numerals used in these descriptions of the seventh and eighth instars correspond to those used by Crumb in his description of the first six instars and refer to Figures 5 and 13 in the bulletin on tobacco cutworms (*1*) which figure the larval head shield and setal chart, respectively, for *Feltia* spp.

[6] RIDGWAY, R. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., illus. Washington, D. C. 1912.

clypeus. Mandibles with four major teeth, the upper somewhat bifid, the lower with a small tooth remote from termination of main tooth. Labrum with two semicircular lobes separated by a narrow rounded notch, paler than frons. The rough epicranium shows the rounded spots far back. Cervical shield olivaceous black with narrow median line hayti gray, integument of neck pale gull gray. The median line back of cervical shield is broken. The areas representing the greatly reduced subdorsal bands are vetiver green, including two broken slender lines on sides. The light area at mesad bases of series II setal spots, the encircling zone of setal spots III, IV, and V, and the V setal spot in its entirety, pale gull gray. Border of median line and dark color of back dark olive gray. I and II setal spots slate black. Setal spots III and IV olive gray. Venter deep slate olive. Anal shield olivaceous black on warm buff, the latter showing in median line and at margins.

The character of skin in the seventh and eighth instars agrees entirely with the description given by Crumb for the sixth instar, except that the "convex, rounded, distinctly isolated, very coarse shiny granules" occasionally range in size up to 0.1 mm each. The adfrontal sutures reach the occipital foramen. Setal tubercle I is about 0.6 mm in longitudinal axis of larva, 0.9 mm wide, and that of II, 0.9 by 1.7 mm.

Setal tubercle I is slightly more than half the diameter, both longitudinal and transverse, of setal tubercle II, each definitely transverse. Tubercle III is slightly larger than I but with less of its surface pigmented. Basal portion of leg claw without tooth. About 20 crochets on each proleg.

LARVAL DEVELOPMENT AND DETERMINATION OF INSTARS

The development of the larva is indicated in Table 1, in which the head measurements of many specimens are averaged, first for all, then for only those becoming adults, then separately by sexes for individuals which became adults after 6 instars, then separately by sexes for individuals which became adults after 7 instars, and lastly for the few females which became adults after 8 instars. Of those reaching the adult stage, 57.4 per cent passed through 6 instars, 38.9 per cent required 7, and 3.7 per cent required 8 instars.

TABLE 1.—*Average head measurements for the entire series and for the individuals of each sex of the black cutworm that matured in 6, 7, and 8 instars, respectively, Webster Groves, Mo.*

Instar	Entire series		Individuals which became adults		Individuals which became adults in 6 instars				Individuals which became adults in 7 instars				Individuals which became adults in 8 instars (no males)	
					Males		Females		Males		Females		Females	
	Males and females	Average head width	Males and females	Average head width	Individuals	Average head width	Individuals	Average head width	Individuals	Average head width	Individuals	Average head width	Individuals	Average head width
	Number	*Mm*	*Number*	*Mm*	*Number*	*Mm*	*Number*	*Mm*	*Number*	*Mm*	*Number*	*Mm*	*Number*	*Mm*
First	60	0.29	34	0.29	17	0.29	8	0.29	5	0.28	4	0.29	------	------
Second	120	.44	70	.45	20	.47	12	.48	20	.42	14	.42	4	0.41
Third	142	.78	85	.79	25	.80	20	.83	24	.77	12	.78	4	.73
Fourth	134	1.38	92	1.39	29	1.59	21	1.53	23	1.99	15	1.20	4	1.04
Fifth	125	2.12	96	2.14	31	2.26	24	2.30	23	1.99	15	1.97	3	1.70
Sixth	113	3.05	97	3.07	30	3.36	24	3.44	24	2.72	16	2.72	3	2.44
Seventh	51	3.67	45	3.61	------	------	------	------	24	3.69	17	3.72	4	3.25
Eighth	4	3.81	4	3.81	------	------	------	------	------	------	------	------	4	3.81

In the analysis of the average sizes of the head capsule for the several instars, it may be noted that the average of the aggregate in the instar regardless of maturity, and the average of those individuals which became adults regardless of sex or number of instars, check up very closely. The averages for the adults which developed completely in six instars and for those which finished in seven and eight instars are fairly approximate in size, both in the first instar and in the last instar, but they do not check up very closely in the intermediate instars, where the growth of the larvae which underwent seven and eight instars, respectively, was retarded as compared with the growth of the 6-instar larvae. The number of individuals in the 7-instar and 8-instar classes may be too small for consistent record for growth in those classes. In the larger class of the 6-instar individuals the averages are more significant. There is not much difference between the head measurements of the males and females in the first three instars, but after that the heads of the males appear to be generally larger than those of the females.

A further analysis of the head widths is given in Table 2, where the maximum and minimum widths of the head capsules are also shown. For the first and second instars the records cover all the larvae under observation. The measurements given for the remaining instars are of those larvae only which finally became adults.

TABLE 2.—*Minimum, maximum, and average head width for the various larval instars of the black cutworm, Webster Groves, Mo.*

Instar	Individuals measured	Width of head capsule			Remarks
		Minimum	Maximum	Average	
	Number	*Mm*	*Mm*	*Mm*	
First	60	0.26	0.35	0.292	Entire series.
Second	120	.36	.52	.442	Do.
Third	90	[a] .61	[a] 1.11	.794	Only those yielding adults.
Fourth	92	.77	2.07	1.390	Do.
Fifth	96	1.09	2.80	2.140	Do.
Sixth	97	1.47	3.94	3.066	Do.
Seventh	45	3.14	3.95	3.610	Do.

[a] The molts represented by the measurements of 0.61 and 1.11 mm occurred in a period of less than 3 days, during which only 1 examination was made.

The head capsule is the least variable major portion of the larva, and the cast mask is the most durable portion of the exuvium. The head, therefore, is a good guide for determining the instar. While the larva is still active, the ocelli may be observed in the new head behind the ocelli of the mask which is about to be cast. Feeding is suspended, often the major part of a day, before molting. By measuring the head promptly after each molt, and again within two or three days after the last observed molt, the instars may be fairly accurately traced. The observation of the shifting ocelli sometimes aided in detecting a stage of development in the instar after which feeding could not be expected. Suspended feeding before a molt was very often used for fixing the dividing line between the feeding of one instar and that of the next. The actual ecdysis was rarely witnessed.

Measurements were generally made with the microscope eyepiece until after the second instar, because of the difficulty of handling

small larvae when making measurements by calipers. Later instars were measured by caliper.

DURATION OF INSTARS

The cages were examined at least once a day, when the food was changed and any exuviae removed and studied, and any details of changes in progress that had taken place since the last examination were noted. Usually the molts occurred between these examinations, and the length of the instar was computed as lasting from an unknown point between two observations to a similar point between two later examinations. For example, an egg hatched between 9 and 9.10 p. m., May 26, and the larva cast its first exuvia between 9.30 a. m., May 28, and 9.30 a. m., May 29; the first-instar period or stadium was, therefore, between 36.33 hours and 60.5 hours. The mean time in this example is 48.41 hours for the duration of the first instar.

Table 3 gives the average range of each instar and of the larval period, by hatching groups, regardless of whether or not the larva reached the adult stage. The first two figures of the group number denote the year. The first two hatching groups from eggs laid September 4 and 5, 1928, hatched between 8.20 and 9 a. m. and 9 a. m. and 4 p. m., respectively, September 10. The third hatching group from eggs of August 27, 1928, hatched between 4 p. m., August 29, and 10.30 a. m., August 30. The explanation for the marked differences in average periods of duration of the first instar is presented under the discussion of effect of temperature. The duration of the instars as recorded may therefore be regarded as fairly representative for the St. Louis district during May, July, August, and September. The first six instars lasted approximately 3, 3, 3, 4, 5, and 7 days, respectively.

TABLE 3.—*Record of the duration of instars of the black cutworm for groups hatching at different times, Webster Groves, Mo., 1928–29*

Group No.	Time eggs were laid	Total of group	First instar		Second instar		Third instar		Fourth instar	
			Individuals	Approximate duration of instar	Individuals	Approximate duration of instar	Individuals	Approximate duration of instar	Individuals	Approximate duration of instar
		Number	*Number*	*Hours*	*Number*	*Hours*	*Number*	*Hours*	*Number*	*Hours*
28727	9.30 a. m., Sept. 4	6	6	32 to 55	6	28 to 75	4	35 to 92	3	83 to 140
	8 a. m., Sept. 5	10	10	30 to 36	10	32 to 83	10	45 to 99	9	66 to 131
28730	4.10 p. m., Aug. 27	12	12	255 to 290	11	117 to 176	9	120 to 178	8	118 to 172
29033–b	2 p. m., May 22, to 3.05 p. m., May 23.	35	35	61 to 96	35	26 to 75	32	41 to 90	31	48 to 93
		4	4	42 to 67	4	19 to 69	3	39 to 88	3	47 to 90
		4	4	61 to 86	4	6 to 60	4	23 to 71	4	50 to 96
		2	2	60 to 86	2	[a] 0 to 52	2	23 to 70	2	51 to 95
		48	48	53 to 89	48	15 to 66	47	33 to 88	42	58 to 112
29111	10.30 a. m., July 4, to 9.15 a. m., July 5.	37	37	45 to 74	37	32 to 84	35	21 to 83	27	21 to 82
29127	10.35 a. m., July 8, to 9.15 a. m., July 9.	11	11	47 to 104	11	16 to 66	9	27 to 73	8	23 to 66
		17	17	27 to 72	17	22 to 74	15	29 to 75	13	25 to 71

[a] These larvae were examined May 29, 9.45 a. m., May 30, 11 a. m., and May 31, 1.45 p. m. It is evident that the duration of the second instar was less than 52 hours and that it was more than 0 hour. There are several instances of successive molts on successive days.

TABLE 3.—*Record of the duration of instars of the black cutworm for groups hatching at different times, Webster Groves, Mo., 1928–29*—Continued

Group No.	Fifth instar		Sixth instar		Seventh instar		Eighth instar		Total larval period	
	Individuals	Approximate duration of instar	Individuals	Approximate duration of instar	Individuals	Approximate duration of instar	Individuals	Approximate duration of instar	Individuals	Approximate duration of stage
	Number	*Hours*	*Number*	*Hours*	*Number*	*Hours*	*Number*	*Hours*	*Number*	*Hours*
28727	3	120 to 172	2	112 to 175	0		0		1	626 to 672
	6	105 to 160	5	125 to 189	2	129 to 193	0		[b] 4	621 to 678
28730	6	119 to 181	5	142 to 206	0		0		1	1,008 to 1,051
29033–b	29	65 to 110	25	142 to 185	5	147 to 187	0		23	543 to 570
	2	57 to 103	2	110 to 156	1	172 to 212	0		1	1,069 to 1,103
	4	70 to 119	4	106 to 150	2	172 to 213	0		4	536 to 551
	2	70 to 119	2	96 to 147	2	172 to 212	0		2	520 to 543
	40	71 to 111	37	113 to 185	5	178 to 226	0		37	531 to 558
29111	25	36 to 84	25	88 to 137	17	151 to 196	0		25	494 to 522
29127	8	48 to 98	8	53 to 100	8	280 to 326	3	180 to 218	8	548 to 602
	11	39 to 85	10	49 to 96	9	157 to 202	1	222 to 262	9	400 to 548

[b] These are three 6-instar and one 7-instar individuals.

The mean average duration of larval instars is given in Table 4.

TABLE 4.—*The mean average duration in hours of larval instars of the black cutworm by cage groups for all records in each instar and for those larvae which became adults in the 6-instar, 7-instar, or 8-instar classes, respectively, Webster Groves, Mo.*

Cage group	Series	First instar	Second instar	Third instar	Fourth instar	Fifth instar	Sixth instar	Seventh instar	Eighth instar	Total larval period [a]
May	Total	73	44	62	78	89	140			
	6-instar	74	42	61	81	99	182			539
	7-instar	70	34	56	74	65	89	179		678
July 4	Total	59	58	57	49	60	113			
	6-instar	65	61	65	50	81	185			506
	7-instar	56	53	43	49	52	84	172		501
July 8	Total	60	45	51	46	67	74	193		
	7-instar	58	41	51	41	67	81	197		532
	8-instar	54	47	48	48	66	52	78	210	614
August	Total	272	146	89	145	150	171			
	6-instar	248	[b]	[b]	109	95	240			1,030
September	Total	38	55	68	105	139	154	161		
	6-instar	47	59	84	176	139	201			647
	7-instar	40	23	43	121	146	105	204		681

[a] Not necessarily the total of the mean averages of the individual periods.
[b] Not determined.

A few individuals made records quite at variance with the mean average duration. One larva of the 6-instar class, hatching July 4, required more than 118 hours in the first instar. One larva of the 6-instar class, hatching in May, in the third instar required less than 32 hours.

Less than 49 hours for the sixth instar was required in the case of a larva of the 7-instar class that hatched in May.

There was no eighth instar in the July 4 or August groups. In the September group one larva attained the eighth instar but was killed to represent that instar.

The entire larval period, that is, from the date of hatching to pupation, lasted less than 492 hours in the case of one 6-instar individual, and less than 563 hours in that of one of the 7-instar larvae that hatched in May; less than 457 hours in that of one of the 6-instar larvae and

less than 482 hours in that of one of the 7-instar class that hatched July 4; less than 474 hours in that of one of the 7-instar; and less than 598 hours in that of one of the 8-instar individuals that hatched July 8.

EFFECT OF TEMPERATURE

The study of time variations in the development of the immature stages in relation to variations of temperature is on the basis of the published records of the St. Louis station of the United States Weather Bureau. The floor of the thermometer shelter is 737 feet above mean sea level, 10 feet above the main roof of the Railway Exchange Building, and about 264 feet above the street level. The records of temperature taken by the Weather Bureau are used because the laboratory instrument was out of service for several weeks during the period of the experiments.

A cool period from August 30 to September 6, 1928, retarded the first instars of the August group, whereas warm weather following September 10 allowed faster growth, as is shown in Table 3, where the mean durations of the first instar in the August group and September 4 series are, respectively, 272 and 43 hours. The retarding influence of cool weather prevailing when the larvae are in the first instar may, as manifested in this example, be felt throughout the life of the larva. The mean averages for the entire larval periods of the August group and of the September 4 series are, respectively, 1,029 and 649 hours, and for the entire cycle from adult to adult are 1,344 and 1,129 hours. This record of contrasting life-cycle reactions to less than optimum temperature in the first larval instar may account for some outbreak phenomena, and is in keeping with the sensitivity recorded by Crumb (*1, p. 54*), which appears automatically to preclude the successful hibernation of any forms at Nashville, Tenn., except pupae developing during a short period in the fall.

Two larvae in the September 4 series were followed through the several instars in relation to daily mean temperatures. The mean duration of the first instar and the mean average temperature for the period were, for the first, 40.47 hours, 78° F.; for the second, 63.8 hours, 79.5°. The mean duration of the second instar and the mean average temperature were 46.25 hours, 82.5°, and 90.25 hours, 76.5°, respectively; third instar, 58.05 hours, 77°, and 86.13 hours, 68°, respectively; fourth instar, 170.08 hours, 65°, and 82.75 hours, 61°, respectively; fifth instar, 131.38 hours, 57°; and 131.47 hours, 57°, respectively; sixth instar, identical records, 201.47 hours, 66°. These two records show relatively speedy development with the warmer temperatures in second and third instars, and the reverse in the first and fourth instars; the larvae made identical records in the fifth and sixth instars with the same temperatures, the preceding irregularities having brought them to the beginning of the fifth instar at the same time. This nonadherence to the generally accepted rule of acceleration with warmth and retardation with cooler temperatures is not understood.

FEEDING EXPERIMENTS

The feeding records are fairly represented in groups in Table 5. The grouping of feeding records in this table is made according to cage group and hatching date of eggs. The first line of averages concerns all of the individuals in a particular instar regardless of whether they became adults or not. Thus, in the series of 35 hatching in one period

in the May group, only 22 reached the pupal stage in six instars and 3 in seven instars and 1 larva was preserved in its eighth instar. The average for the entire larval period of the group, therefore, could not be obtained because of the irregularities both in number of specimens and of instars and because of the division into the two classes of 6-instar and 7-instar maturing larvae. The average quantities of foliage eaten by all larvae of each of the seven instars, however, are given for the three series of groups.

TABLE 5.—*Average quantities of food eaten by larvae of the black cutworm during the various instars, indicated by square inches of leaf surface, Webster Groves, Mo.*

Group No.	Date eggs were laid	First instar		Second instar		Third instar	
		Individuals	Foliage eaten [a]	Individuals	Foliage eaten	Individuals	Foliage eaten
		Number	*Sq. in.*	*Number*	*Sq. in*	*Number*	*Sq. in*
29033-b	May 22–23	35	0.044	35	0.119	33	0.528
		4	.026	4	.079	3	.321
		4	.051	4	.086	4	.300
		2	.026	2	.101	2	.495
		54	.042	49	.111	47	.511
29111	July 4–5	5	.046	5	.112	5	.329
29127	July 8–9	5	.024	5	.128	4	.270
Total or average		109	.041	104	.112	98	.483
Average quantity of foliage eaten by 65 larvae that eventually became adults		----------	.037	----------	.114	----------	.540

Group No.	Date eggs were laid	Fourth instar		Fifth instar		Sixth instar		Seventh instar	
		Individuals	Foliage eaten	Individuals	Foliage eaten	Individuals	Foliage eaten	Individuals	Foliage eaten
		Number	*Sq. in.*	*Number*	*Sq. in.*	*Number*	*Sq. in.*	*Number*	*Sq. in.*
29033-b	May 22–23	32	1.51	29	7.56	26	48.69	3	63.82
		3	1.33	2	4.70	2	31.78	1	61.96
		4	1.36	4	4.24	4	36.36	2	60.36
		2	1.40	2	2.95	2	29.18	1	62.42
		43	1.57	40	6.15	38	49.19	6	53.38
29111	July 4–5	3	.68	2	2.61	2	25.29	1	42.88
29127	July 8–9	2	.95	2	2.57	2	15.65	2	28.70
Total or average		89	1.49	81	6.27	76	45.85	16	53.57
Average quantity to foliage eaten by 65 larvae that eventually became adults		--------	1.55	--------	6.01	--------	46.48	--------	[b] 52.53

[a] Average per individual in all cases in the table.

[b] Quantity eaten by 14 larvae.

In Table 6 are recorded the average quantities of foliage eaten in the several instars by all larvae which became adults in six instars, with separate averages for individuals which became males and females, in the May and July 4 groups. Inasmuch as only one individual in each of a number of the groups became an adult, several of the records are those of individuals.

TABLE 6.—*Average quantities of foliage consumed by larvae of the black cutworm, May and July 4 groups, that reached maturity after only six instars, and averages by sexes, Webster Groves, Mo.*

Record No.	Individuals	Foliage eaten by larvae of the—						
		First instar	Second instar	Third instar	Fourth instar	Fifth instar	Sixth instar	Total
Larvae of the May group:	*Number*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*
1	19	0.044	0.13	0.51	1.71	7.97	55.90	66.26
2	1	.032	.07	.47	1.52	7.10	54.66	63.85
3	2	.027	.10	.38	1.26	4.62	58.30	64.69
4	1	.027	.13	.49	1.43	4.48	48.80	55.36
5	27	.035	.12	.50	1.68	6.33	56.61	65.27
Larvae of the July 4 group:								
6	1	.070	.20	.66	1.19	3.03	39.61	44.76
Total or average	51	.039	.12	.50	1.66	6.79	55.89	65.00
Averaged by sexes:								
Male	29	.039	.12	.51	1.69	7.12	52.79	62.62
Female	22	.040	.12	.49	1.62	6.35	59.52	68.14

[a] The five sets of records for the May group in Table 3 are represented in the five records here given.

In Table 7 are recorded the averages for all larvae yielding adults in seven instars, and the separate averages for individuals yielding males and females, in the May, July 4, and July 8 groups. On an average, the female is decidedly the heavier feeder. The records of feeding in the earlier instars are not constantly heavier for the females, but in the last three instars they are markedly heavier. The duration of the instar, and hence the quantity of food eaten, is dependent largely upon the prevailing temperature.

TABLE 7.—*Average quantities of foliage consumed by larvae of the black cutworm, May, July 4, and July 8 groups, that reached maturity after seven instars, and averages by sexes, Webster Groves, Mo.*

Record No.	Individuals	Foliage consumed by larvae of the—							
		First instar	Second instar	Third instar	Fourth instar	Fifth instar	Sixth instar	Seventh instar	Total
Larvae of the May group: [a]	*Number*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*
1	2	0.028	0.10	0.53	0.94	4.27	16.58	64.44	86.89
2	1	.035	.09	.24	.97	2.30	8.90	61.96	74.49
3	2	.074	.06	.22	1.46	3.85	14.42	60.36	80.44
4	1	.024	.07	.50	1.38	1.42	9.56	62.42	75.37
5	5	.028	.06	.41	1.29	3.38	14.67	52.23	72.07
Larva of the July 4 group:									
6	1	.022	.03	.10	.43	2.19	10.97	42.83	56.57
Larvae of the July 8 group:									
7	2	.015	.15	.37	.94	2.58	15.64	28.72	48.42
Total or average	14	.032	.08	.37	1.14	3.16	14.00	52.53	71.31
Average by sexes:									
Male	7	.038	.07	.31	1.14	2.63	11.36	51.93	67.48
Female	7	.027	.09	.43	1.14	3.69	16.65	53.12	75.15

[a] The 5 sets of records for the May group in Table 3 are represented in the 5 records here given.

The progression in quantity of feeding done in each instar in both the 6-instar and the 7-instar maturing classes is shown in Figures 1 and 2. The averages for the 6-instar class (Table 6) are represented by squares in Figure 1, the outside square representing the total area of foliage consumed. The correct measures of these squares are 0.197, 0.35, 0.71, 1.29, 2.6, 7.34, and 8.06 inches. The averages for the 7-instar class (Table 7) are represented by the squares in Figure 2. The correct measurements of the sides are 0.18, 0.287, 0.61, 1.07, 1.77, 3.74, 7.2, and 8.44 inches, the outside square representing the total quantity eaten.

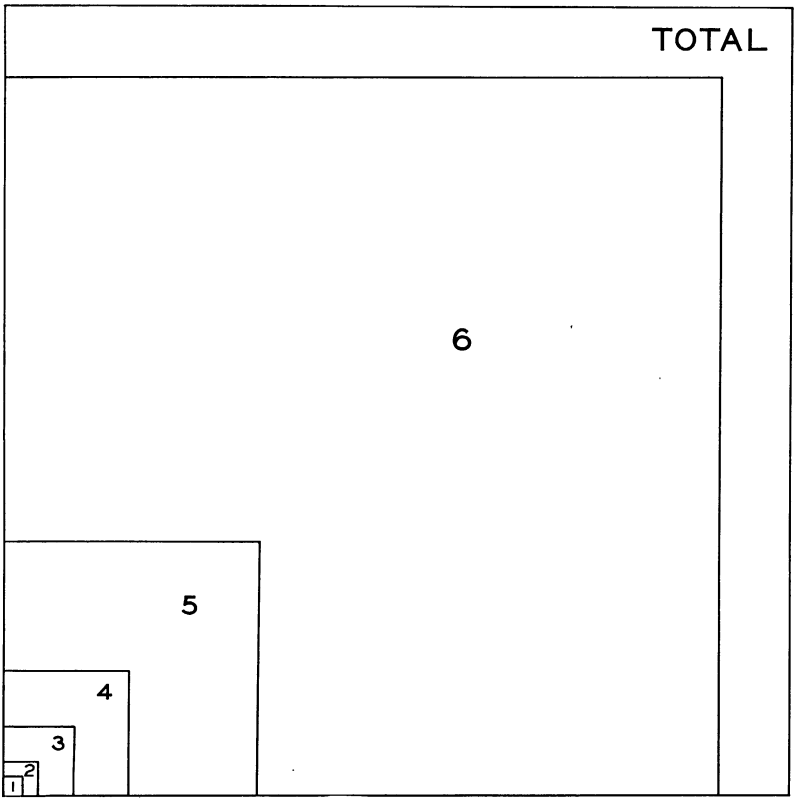

FIGURE 1.—Comparative area of foliage consumed in the successive instars by larvae of the black cutworm that matured in six instars. The numbers in the superimposed squares indicate the instars, and the outside square represents the total area consumed during the entire larval period

The entire larval period is approximately the same for the 6-instar and 7-instar larvae, but the quantity of food consumed is greater in the 7-instar than in the 6-instar class of the May group. The quantity of food consumed by the 7-instar larvae of the July 8 group is not a satisfactory record, as there were only two specimens in the class. However, the mean temperature for the period of the larval stages of the July 8 group, July 13 to August 3 (81° F.), was 8° higher than for that of the May group, May 23 to June 18 (73°). This would indicate that larvae go through the feeding stage with less aggregate feeding when the weather is warm than when it is cooler.

The progression in quantity of feed consumed and the time spent in each instar are shown graphically in Figure 3. The dotted line represents the May larvae maturing in 6 instars, the solid line the May larvae maturing in 7 instars, and the dash line the July 8 larvae maturing in 7 instars. Only the average duration of the instars and feeding records of the individuals which became adults were used.

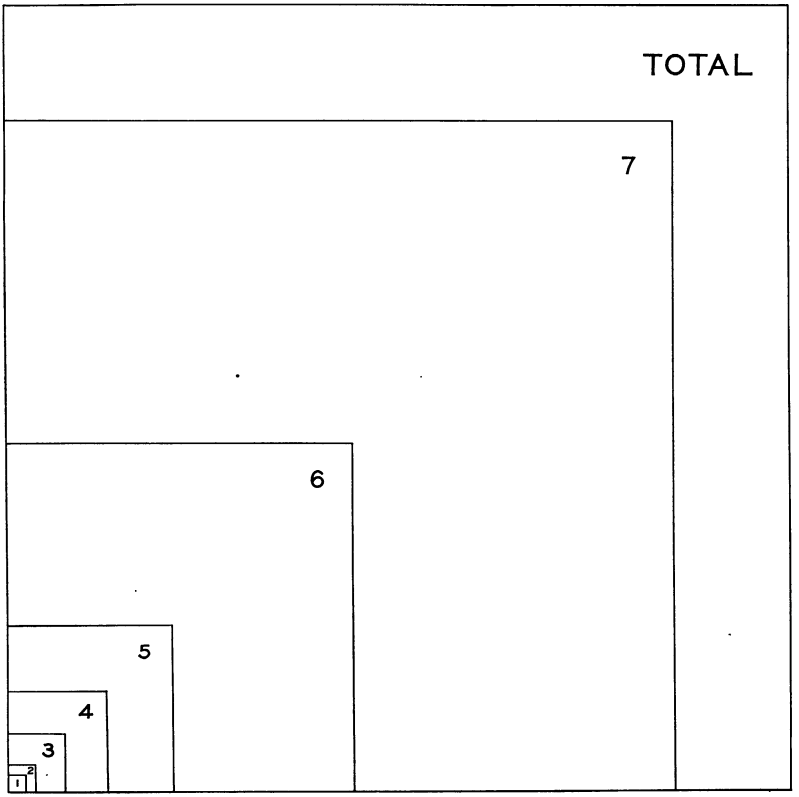

FIGURE 2.—Comparative area of foliage consumed in the successive instars by larvae of the black cutworm that matured in seven instars. The numbers in the superimposed squares indicate the instars, and the outside square represents the total area consumed during the entire larval period

DISCUSSION

Garman and Jewett (*4*) determined that the corn ear worm, *Heliothis obsoleta* Fab., had three complete broods a year at Lexington, Ky., the first brood (July) requiring 12 to 17 days to mature, the second brood (August) 12 to 19 days, and the third brood (September, 1908) 10 to 14 days and (September–October, 1909) 23 to 36 days. The instar periods averaged from 10 records of the first brood were, respectively, 2.63, 2.50, 2.08, 2.42, 2.58, and 3.58 days. The larval development was swiftest in warm weather and slowest in cool weather. The time of development of the last brood was normally lengthened by the cool weather.

Several writers on the instars of lepidopterous larvae of the cutworm family, or of larvae behaving much like the cutworms in their

method of work, including Davis and Satterthwait (*2*) on the true army worm, *Cirphis unipuncta* Haw., Parker, Strand, and Seamans (*7*) on the pale western cutworm, *Porosagrotis orthogonia* Morr., and Luginbill (*6*) on the fall army worm, *Laphygma frugiperda* S. and A., recorded the duration of the second, third, and fourth instars as shorter than that of the first, and that of the sixth as much longer.

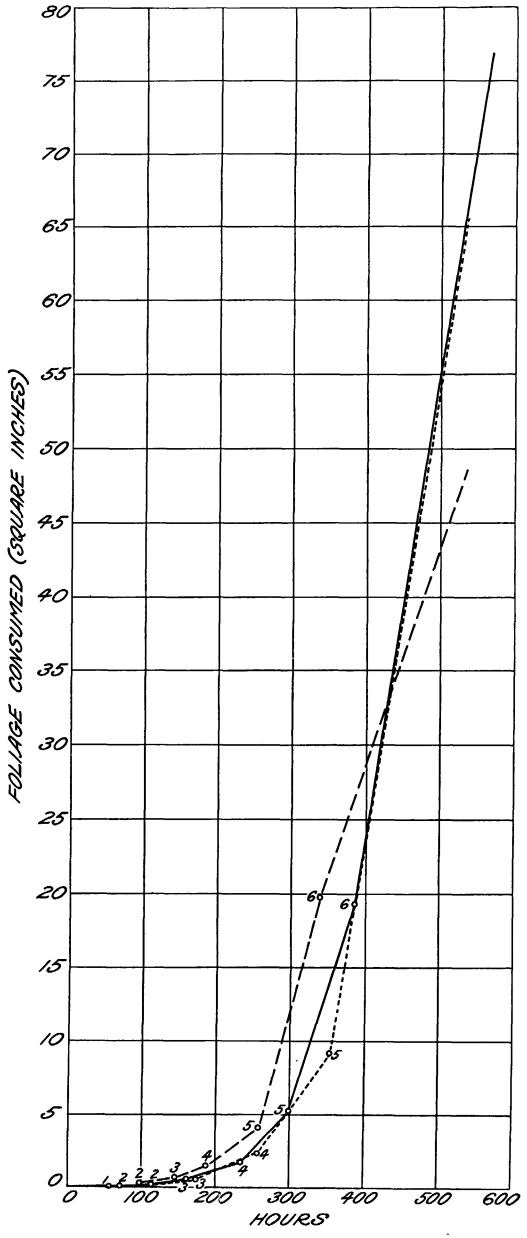

FIGURE 3.—Area of foliage consumed by the black cutworm in various larval instars. The dotted line represents the larvae of the May group maturing after 6 instars, the solid line those of the May group requiring 7 instars, and the broken line larvae of the July 8 group maturing in 7 instars. The figures at points where the lines change direction mark the close of the instars

Crumb (*1, p. 58*) states that in a series of tests on *Agrotis ypsilon* the six instars required, respectively, 2, 2, 3, 4, 4, and 5 days, a shorter duration for the first instar, in relation to that of the second, third, and fourth, than usual, but the usual substantially increased duration for the sixth.

In the present investigation of the black cutworm, effort was made to give all the larvae equally good food. Thus there is no recognized cause for the development of seven or eight instars in the several instances recorded. The record of Decker (*3, p. 144*) furnishes an entirely satisfactory explanation for the 7 to 11 instars in the 4-lined borer, *Luperina stipata* Morr., because of the continuous feeding of unfavorable parts of the plant to certain individuals. Crumb (*1, p. 134, 138*) found a seventh instar in the spotted-sided cutworm, *Agrotis badinodis* Grt., and the spotted cutworm, *Agrotis c-nigrum* L., but made no comment.

It is a common observation that a high temperature speeds feeding and growth and a low temperature checks feeding and growth. The present investigation included temperatures sufficiently low almost to suspend all development for a week at a time. Decker (*3, p. 146*) used controlled temperatures in certain experiments and reported that—

> Larvae reared in an incubator at 27° C. developed almost twice as fast as those reared at 20° C., about two and one-half times as fast as those reared in the screened laboratory, and about four times as fast as those reared at 13° C.

Where there are several generations a year, the duration of the last generation is likely to be lengthened by cooler weather. Garman and Jewett (*4, p. 539*) found three complete broods and a fractional fourth for the corn ear worm at Lexington, Ky. The three broods required approximately 30 days each. The fourth brood was definitely imperfect on account of frost.

Watson (*8, p. 1*) indicates that the late fall weather may affect the velvetbean caterpillar, *Anticarsia gemmatilis* Hbn., in the statement that "late in the fall, a few individuals molted seven times."

Parker, Strand, and Seamans (*7, p. 299*) indicate that the extreme variation in length of life of larvae of the pale western cutworm may be chargeable to food supply rather than low temperature, as the larvae migrate little or not at all, and may remain unharmed through lack of food for several weeks in the feeding season.

Luginbill (*6, p. 44*) records the fact that the larval period in the fall brood of the fall army worm at Columbia, S. C., averages 29 days, whereas that of the summer brood averages 14 days. This is obviously a slowing down with reduced temperatures.

Holloway, Haley, and Loftin (*5, p. 27–28*) furnish a tabulated summary showing the numbers of instars of the sugarcane borer, *Diatraea saccharalis* Fab., and numbers of examples in relation to average mean temperatures. Ten instars, the greatest number, was coincident with the lowest average mean temperature occurring in the experiment. Although seven instars occurred at an average mean temperature of 78.9° F., the prevalence of increased numbers of instars at average mean temperatures of 69.8° and lower marks a definite tendency to greater numbers of instars at the lower temperatures. There appeared also to be a slight tendency for instars to increase in number with the highest average mean temperatures. The length of the developmental period of the larvae was great, 242 or more days, at average mean temperatures of 61.4° and lower, and moderate to short, 19 to 76 days, at average mean temperatures of 65.3° and higher.

Crumb (*1*) shows the lengthening of the larval stage of *Agrotis ypsilon* (*p. 57*) at cooler temperatures in the fall and of the granulate cutworm, *Feltia annexa* Treit., (*p. 79–80*). In the variegated cutworm, *Lycophotia margaritosa saucia* Hbn. (*p. 112–113*), the reaction to cool weather was regular in the tardy larval development in the spring at average mean temperatures of 61° F. and lower, and in the summer, but the larval period lengthened beyond the spring periods at September average mean temperatures not lower than 73.5°.

Watson (*8*) measured the quantity of food consumed by weighing the foliage before and after feeding, preventing all appreciable evaporation by keeping leaf stems in water, and all under a bell jar.

Davis and Satterthwait (*2*) investigated the quantities of food consumed by larvae of the true army worm, using 153 individually caged larvae in September and October. The quantity of corn foliage

consumed in the several instars averaged, respectively, 0.03, 0.10, 0.34, 1.20, 5.36, and 34.13 square inches each, an average total of 41.39 square inches for each larva.

Luginbill (*6*) recorded the quantity of food consumed by larvae of the fall army worm. Two larvae were observed while feeding, corn leaves were used exclusively, and the quantity eaten was measured daily. One larva ate the equivalent of 90.2 cm^2 plus an area of 153 mm^2 skeletonized; the other ate 91.8 cm^2 of foliage and skeletonized an area of 192 mm^2. The fall army worm thus matures on about one-third the corn foliage required by the black cutworm and requires appreciably less time in the larval stage.

SUMMARY

There are three generations of the black cutworm a year at Webster Groves, Mo. Unseasonably cool weather may greatly retard larval development in the first instar and probably serves to increase the mortality rate in later stages of these larvae.

The growth of larvae in general, judged by head measurements, is approximate to one and a half times the size of the preceding head width, if the growth is completed in six instars. Where more instars occur, the increase after the sixth is greatly reduced for the subsequent stages. Increases in size between instars, especially in the first three, may be much greater; rarely the width in the second instar measures twice the width in the first.

The quantities of food eaten in the first three instars are small, then increase abruptly, especially between the fifth and sixth instars, in the individuals maturing in six instars. The measurement of food eaten was possible when corn foliage alone was supplied. In nature, the larvae bite off and then discard entire plants, thus getting an unknown volume of plant tissue and wasting perhaps a thousand times more than they consume. When fed corn foliage exclusively, a larva which undergoes six instars will eat the equivalent of 65 square inches of corn leaf.

The feeding of the larvae which eventually yield females is appreciably heavier than that of larvae which yield males, and is lighter in the July than in the May brood.

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