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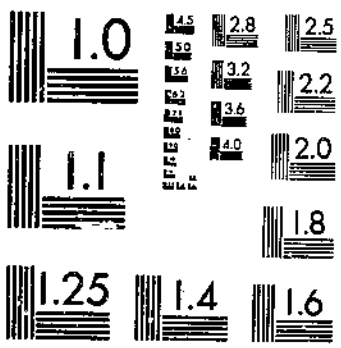

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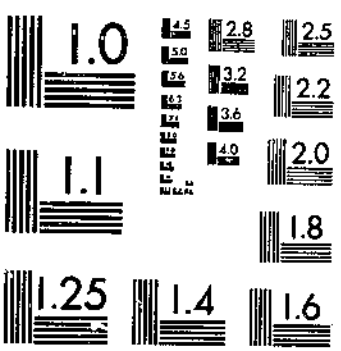

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Hibernation of the Corn Earworm in Southeastern Georgia [1]

By G. W. BARBER, *associate entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine*

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INTRODUCTION

A study of the hibernation of the corn earworm (*Heliothis armigera* (Hbn.)) in central Virginia [2] from 1921 to 1928 showed that in that latitude an average of only 5 percent of the larvae that entered the soil during the fall survived to emerge as moths the following summer. At that time satisfactory information on hibernation of the insect farther south was not available, but was desired as an aid to obtaining an understanding of its seasonal occurrence and populations in the Southern States, and to determine the usefulness of cultural measures in its control. A study of the hibernation of the corn earworm was begun in Chatham County, Ga., in 1930 and continued until 1933, and the results are presented in this bulletin.

THE ENVIRONMENT

All the experiments herein discussed were conducted in one locality in southeastern Georgia. The soil was a light sandy loam of the following percentage composition: Fine gravel and coarse and medium

[1] Received for publication May 8, 1941.

[2] PHILLIPS, W. J., and BARBER, GEORGE W. A STUDY OF HIBERNATION OF THE CORN EARWORM IN VIRGINIA. Va. Agr. Expt. Sta. Tech. Bul. 40, 24 pp., illus. 1929.

sand, 1.4; fine sand, 75.6; very fine sand, 11.4; silt and clay, 11.5; and organic matter, 2.3. It had a pH value of 4.35.

In this locality the period of hibernation, from October to April, inclusive, is a comparatively dry season; the period from May to September, inclusive, while the insect is active, is a comparatively wet season. According to United States Weather Bureau data for 1932 the mean annual precipitation at this locality was 48.18 inches. Of this amount 20.17 inches fell from October to April, inclusive, or an average of 2.88 inches per month. During the period May to September, inclusive, 28.01 inches fell, or an average of 5.60 inches per month.

The rare freezing of the soil for brief periods usually occurred in the first inch below the surface. During the winter of 1930–31 temperatures of 32° F. or lower occurred on 8 days, the minimum being 28°; in 1931–32 freezing temperatures occurred on 5 days, the minimum being 24°; and in 1932–33 freezing temperatures occurred on 6 days, the minimum being 22°.

The period from May to September, inclusive, was continuously warm. The maximum shade temperature was 90° F. or higher on 68 days in 1930, on 66 in 1931, and on 63 days in 1932.

In their hibernation burrows the pupae probably were never subjected to freezing temperature. On the other hand, their environment was continuously warm for long periods in spring and fall, and often during winter.

METHOD OF STUDY

The use of cages was necessary in order to cause the larvae to enter the soil of a limited area, as well as to protect the larvae and pupae from attack by soil fauna, such as moles, and to permit the capture of the moths as they emerged.

Cages similar to those used in earlier studies were adopted. These were constructed of four boards ⅞ inch thick, 10 inches wide, and 30 inches long, nailed together to form a frame 10 inches deep. Covers, 2 inches deep, with a top of wire screen were attached with hinges and hooks so that they could be opened easily. The cages were painted with linseed oil and with green paint to preserve the wood. Series of these cages were set in the soil that has been described. Since the cages remained in one place during the entire period of the experiments, the environmental conditions were similar each year.

The larvae used in the experiments usually were collected from corn ears as sixth or last instars. They were isolated in 2-ounce tin salve boxes and given fresh corn kernels as food daily until they approached maturity. Then the covers of the salve boxes were removed and the boxes, containing the larvae and fresh food, were inverted on the soil so that the larvae could enter the soil as soon as they were ready to do so. Early in the summer, before corn ears became available, larvae were collected from corn tassels. In the few periods when larvae were unobtainable in the field, they were reared singly in the salve boxes mentioned, being fed fresh food once a day, or more frequently as they attained the later instars.

Series of experiments were begun at intervals throughout the period from May to September during the years 1930 to 1932, inclusive, in an attempt to represent, roughly, the number of generations

of the insect possible annually. Some of the cages were examined during the same year in which the larvae entered the soil, and others were examined the following summer after the insects had overwintered.

The soil of the cages was examined by shaving it off horizontally with a trowel, working downward so as to find and follow the emergence burrows and recover any of the insects present at the bottoms of them.

SEASONAL HISTORY OF THE INSECT

Depending on earliness of the season, the time of first emergence of moths ranged from the first week of April to the first week of May in different years. By the end of September most of the insects occurred as resting pupae in the soil. Although during April and May the insect passed through a generation in about 5 weeks, in midsummer a generation was completed in about a month, but again about 5 weeks were required during September or early in October. Therefore it was possible for the progeny of the earliest moths which emerged in a given year to pass through five generations if they were continuously active. The latest moths emerged from hibernation on July 23 in 1931 and on July 27 in 1933. It was possible that the progeny of these moths passed through only a single generation, for by the time the larvae hatching from their eggs had matured the species was beginning to rest as pupae in increasing numbers.

Long before the last moths had emerged from hibernation the progeny of the individuals that emerged earliest had already passed through as many as three generations. A continuous overlapping of generations therefore occurred in this area, resulting in the presence of a continuous population of all stages in the field throughout the summer. Probably this explains why corn was uniformly attacked whenever it occurred in attractive stages of growth.

PUPATION

When the larvae become full-grown they migrate, or fall, from the food plant to the ground and seek suitable places to enter the soil. They dig downward from less than 1 inch to more than 10 inches, but usually from 2 to 6 inches, below the surface, filling in their entrance burrows as they dig. From the deepest point they then dig emergence burrows for the prospective moths to within a half inch of the soil surface. These upward-directed burrows are left clear of soil, and the walls are compacted and lined with a viscid material and a few strands of silk to help maintain them intact. This labor is completed within 1 or 2 days, and then the larvae retreat to the lowest part of their emergence burrows, where, within a few days, they transform into pupae. During the summer the pupae remain in this position for the 2 weeks or less until moths emerge. Overwintering pupae, however, may remain quiescent in their burrows 9 months or more.

When Larvae Entered the Soil To Pupate

As has been indicated, larvae began to enter the soil to pupate about 5 weeks after the first moth had emerged in a given season. Early in the season, when corn was not available in stages of growth

attractive to the insect, and late in the season after corn had ripened the larvae developed on other host plants, especially toad flax (*Linaria canadensis* (L.) Dum.) in the spring, and stick tight (*Meibomia purpurea* (Mill.) Vail.) in the fall. Thus, because of the length of the period during which moths were emerging from hibernation, larvae were continually entering the soil throughout the season. Of course, this was not true of any one field of corn, for the time during which larvae entered the soil of a given field depended on the time when the ears were available. In any one field larvae entered the soil continuously during only 2 or 3 weeks, from the time when the ears in the field were in roasting-ear stage to the time when the kernels had become hard.

Fate of Larvae That Entered the Soil

Since larvae were entering the soil daily over a period of 4 or 5 months, they naturally encountered very different soil conditions within this period. These different environmental conditions affected the depth to which the larvae dug, the rate of survival of both larvae and pupae, and the time when the moths emerged. The fate of larvae that entered the soil of experimental cages during the 3-year period is summarized in table 1.

TABLE 1.—*Fate of corn earworms that entered the soil in cages during different monthly periods of the years 1930 to 1932, inclusive, Chatham County, Ga.*

SOIL OF CAGES EXAMINED THE SAME YEAR THAT LARVAE MATURED

When larvae entered soil	Cages observed	Years	Total larvae	Fate of larvae that entered the soil to pupate									
				Emerged as moths		Survived as pupae		Died as larvae		Died as pupae		Total survival	
	No.	*No.*	*No.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
May 15 to June 14	3	2	250	148	59.20	56	22.40	31	12.40	15	6.00	204	81.60
June 15 to July 14	5	3	450	298	66.22	24	5.33	80	17.78	48	10.67	322	71.55
July 15 to Aug. 14	6	3	550	354	64.37	56	10.18	45	8.18	95	17.27	410	74.55
Aug. 15 to Sept. 14	4	2	350	99	28.29	172	49.14	43	12.29	36	10.29	271	77.43
Total	------	------	1,600	899	56.19	308	19.25	199	12.44	[1] 194	12.12	1,207	75.44

SOIL OF CAGES EXAMINED AFTER HIBERNATION OF LARVAE

May 15 to June 14	1	1	100	62	62.00	0	0	24	24.00	14	14.00	62	62.00
June 15 to July 14	1	1	100	52	52.00	0	0	2	2.00	46	46.00	52	52.00
July 15 to Aug. 14	2	2	200	138	69.00	0	0	12	6.00	50	25.00	138	69.00
Aug. 15 to Sept. 14	14	3	1,400	664	47.43	2	.14	180	12.86	554	39.57	666	47.57
Total	------	-----	1,800	916	50.89	2	.11	218	12.11	[2] 664	36.89	918	51.00

[1] Includes 13 killed by parasitic flies.
[2] Includes 14 killed by parasitic flies.

In different experiments from none to 35 percent of the larvae died soon after entering the soil, but usually not before they had completed their burrows. Mortality of burrowing larvae was especially high when heavy rain fell while they were digging. Such larvae were drowned in their burrows, especially if they had become inactive prepupae and could not crawl to the surface. On the other hand, if there was a heavy rain soon after larvae began to dig, they left their

burrows and sought protection elsewhere. In cornfields they were observed to crawl onto corn plants or other vegetation, returning to the soil after the storm had passed.

The percentage that perished as pupae in the cages was extremely variable. In cages examined during the same year in which the larvae had entered the soil, the pupal mortality was found to range from 4 to 46 percent, and in cages examined after hibernation pupal mortality ranged from 3 to 46 percent. On an average, however, mortality of pupae that passed the winter in cages was about three times as great as in cages examined during the same year in which the larvae had entered the soil. During the same year in which larvae entered the soil, survival, consisting of moths that had emerged and living pupae remaining in the soil at the time cages were examined, ranged from 44 to 88 percent. In cages that remained undisturbed over winter, the soil of which was examined the following summer, survival, with few exceptions consisting of emerged moths, ranged from 30 to 80 percent.

Tolerance of Earworm Pupae to Heat

In the area in which these studies were made the temperature of the upper inch or two of soil, when not shaded by plants, commonly reached 100° F. or more during the hours of sunshine from June to September. These conditions did not seem to be injurious to the pupae of the corn earworm. In 17 cages established at various periods during the summers of 1930 to 1932, inclusive, and examined during the season of installation, 1,303 pupae were recovered, of which 12.36 percent were found at depths of 2 inches or less and 87.64 percent at depths of more than 2 inches below the surface. Of the pupae in the upper 2 inches 94.41 percent were alive or had produced moths, whereas of the pupae below 2 inches in the soil 93.43 percent were alive or had produced moths. One pupa was found on the surface of the soil, where it had been exposed to sunshine during the entire pupal period. Nevertheless a moth emerged from this individual at the usual time. While the soil into which pupae dug during summer was usually shaded by plants during part of the day at least, observations seem to show that shading is not usually necessary for survival of pupae even when they are located only slightly below the surface of the soil.

Parasitization

The corn earworms that feed in corn ears are remarkably free from parasitization. Only a single species, a tachinid fly, *Archytas incerta* (Macq.), emerged from collected larvae used in the experiments described. Of the 3,400 larvae listed in table 1, 27 individuals, or 0.79 percent, were attacked by this parasite. Of a total of 5,450 larvae that entered the soil between May 15 and September 14 during 1930 to 1932, inclusive, 41, or 0.75 percent, were attacked by the parasite. No parasites were reared from larvae that entered the soil from June 15 to August 14, but 2.37 percent of 800 that entered the soil from May 15 to June 14 and 0.66 percent of 3,350 that entered the soil between August 15 and September 14, inclusive, were parasitized by *A. incerta*.

DEPTH OF PUPAL CHAMBERS IN THE SOIL IN RELATION TO VARIOUS FACTORS

Series of cages were stocked with larvae monthly from May to September, inclusive, in 1930, 1931, and 1932, so as roughly to represent generations. Although the depth to which larvae dug, and consequently the depth below the surface at which pupae were recovered in these cages, was variable and depended on several environmental factors, 90.23 percent of the pupae recovered were found between 1 and 6 inches below the surface. The average depth of 2,918 pupae recovered was 3.98 inches. Table 2 gives a general summary of the depths at which pupae were recovered.

TABLE 2.—*Depth of pupae of the corn earworm below the surface of the soil in cages stocked with larvae during different monthly periods of the years 1930 to 1932, inclusive, Chatham County, Ga.*

Date when larvae entered the soil	Years	Larvae installed	Pupae recovered	Proportions of pupae found at the stated depths, in inches					
				1 or less	1.1 to 2	2.1 to 3	3.1 to 4	4.1 to 5	5.1 to 6
	Number	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
May 15 to June 14	2	550	295	0.34	14.58	34.91	22.37	17.97	5.76
June 15 to July 14	3	550	468	.21	11.75	33.76	24.57	16.88	9.19
July 15 to Aug. 14	3	750	621	.48	14.82	34.62	19.16	14.17	9.99
Aug. 15 to Sept. 14	3	1,750	1,534	.26	4.49	14.86	18.78	25.49	22.75
Totals		3,400	2,918	.31	8.88	24.73	20.14	20.94	16.14

Date when larvae entered the soil	Years	Proportions of pupae found at the stated depths, in inches					Average depth of pupae below surface of soil	Proportion of individuals recovered as pupae
		6.1 to 7	7.1 to 8	8.1 to 9	9.1 to 10	10.1 to 11		
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Inches*	*Percent*
May 15 to June 14	2	2.71	1.02	0.34	0	0	3.33	84.29
June 15 to July 14	3	2.78	.86	0	0	0	3.44	85.09
July 15 to Aug. 14	3	4.83	1.29	.32	.32	0	3.47	82.80
Aug. 15 to Sept. 14	3	10.10	2.35	.59	.19	.13	4.48	87.66
Totals		7.06	1.75	.41	.17	.07	[1]3.08	85.82

[1] This is a simple mean of the figures for each period; the weighted mean would be 3.98.

SOIL MOISTURE

The departure from the normal in inches of rainfall for the period May to September, inclusive, was −5.09 in 1930, −15.10 in 1931, and +4.79 in 1932. Thus during the 3-year period larvae experienced dry, very dry, or moist soil, respectively, into which to dig. The year 1931 may be termed a drought year, as every month was deficient in rainfall, and during the entire year only 22 inches of rain fell, a deficiency, as compared with a normal, of 26.21 inches. Variation in precipitation during August and September was particularly striking. In 1930 the rainfall during August and September was −1.75, in 1931 it was −8.50, and in 1932 it was +6.63 inches, as compared with the normal. The effect of these conditions on the earworms that dug into the soil during August and September is summarized in table 3. During the very dry year of 1931, larvae dug to greater depths below the surface, on an average, than had been observed previously anywhere, the average depth being 4.94 inches. In

1932, when more than normal rainfall occurred during these months, larvae dug on an average 3.92 inches below the surface or an inch less than in the preceding dry year.

TABLE 3.—*Comparison of the depths below the surface of the soil to which corn earworms dug between August 15 and September 14 of 3 years when precipitation was approximately normal, deficient, or in excess. Chatham County, Ga.*

Year	Cages	Larvae installed	Pupae recovered	Individuals recovered as pupae	Average depth of pupae below surface of soil	Precipitation during August and September, deviation from normal	Proportion of pupae found at the stated depths, in inches	
							1 or less	1.1 to 2
	Number	*Number*	*Number*	*Percent*	*Inches*	*Inches*	*Percent*	*Percent*
1930	5	500	577	75.40	4.66	−1.75	0.26	1.06
1931	7	650	567	87.23	4.94	−8.50	0	1.59
1932	6	600	590	98.33	3.92	+6.63	.51	9.49

Year	Proportion of pupae found at the stated depths, in inches								
	2.1 to 3	3.1 to 4	4.1 to 5	5.1 to 6	6.1 to 7	7.1 to 8	8.1 to 9	9.1 to 10	10.1 to 11
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1930	10.35	18.04	30.50	26.26	11.14	1.86	0.53	0	0
1931	10.23	16.93	23.99	26.45	14.99	4.06	1.06	.35	.35
1932	22.20	21.02	23.73	16.95	4.74	1.02	.17	.17	0

Similar results were obtained in an experiment under controlled conditions, a summary of which is given in table 4. Two wooden cages with wooden bottoms, similar to those used outdoors, but which were 36 inches square and 12 inches deep, were placed in an insectary, protected from rain. Each was filled with soil to a depth of 10 inches. The soil in each cage was firmed, but that in one cage became very dry through evaporation, while that of the second cage was kept moist by frequent applications of water. A total of 125 larvae were allowed to dig into the soil of each cage in the usual manner. On examination of the soil after moths had emerged, it was found that in the dry soil larvae had dug an average of 0.55 inch deeper than in the moist soil. The very dry soil was also less satisfactory for survival, and of individuals that entered it 6 times as many perished as of those that entered the moist soil.

TABLE 4.—*Effect of soil moisture on survival of corn earworms that entered such soils to pupate, Chatham County, Ga., 1932*

[Larvae were collected from corn tassels and entered the soil from June 2 to 10, the moths emerging from June 20 to 30. The soil was examined on July 9]

Condition of soil	Larvae installed	Survivals						Mortality						Average depth of pupation below surface
		Moths emerged		Living pupae		Total		As larvae		As pupae		Total		
	No.	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*In.*
Moist	125	115	92.0	6	4.8	121	96.8	4	3.2	0	0	4	3.2	1.53
Dry	125	99	79.2	2	1.6	101	80.8	12	9.6	[1] 12	9.6	24	19.2	2.11

[1] Three killed by parasitic flies.

Soil Texture

Since full-grown larvae were continuously entering the soil from May to September, inclusive, the physical condition of the soil they encountered was quite different at different periods. After the cultivation of corn the soil became more firmly packed as the season advanced, especially under the influence of rainfall. Larvae that matured in May or June often encountered soil that had been cultivated recently and was loose and friable. Those that entered the soil later in the season encountered soil that had become progressively harder. In the firm soil the emergence burrows were more easily made and remained open more consistently and for longer periods, and therefore were dug deeper. The results of an experiment to determine the effect of physical condition of the soil in two cages on the depth to which larvae dug and on survival are summarized in table 5. On an average larvae dug 0.45 inch deeper in the firm than in the loose soil. Because the burrows did not remain open so well in the loose soil, 26.4 percent of the moths emerging in this soil died before they were able to reach the surface. The number of individuals that died as larvae and pupae was also greater in the loose soil. Furthermore, possibly because they occurred at greater depths below the surface, many more pupae delayed emergence in well-packed than in loose soil.

Table 5.—*Effect of soil condition on the survival of the corn earworms that entered it to pupate, Chatham County, Ga., 1932*

[Larvae were collected from corn tassels and entered the soil from May 20 to 30, the moths emerging from June 3 to 18. The soil was examined on July 11]

Physical condition of the soil	Larvae installed	Survivals			Mortality				Average depth of pupae
		Emerged moths	Pupae	Total	Died as moths in the soil	Died as pupae	Died as larvae	Total	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Inches*
Normally packed	100	54	34	88	0	3	9	12	3.23
Loose, for a depth of 1 foot, as if recently cultivated	100	53	1	54	19	9	18	46	2.78

Food of Larvae

Larvae reared on green pods of string beans behaved quite differently from those collected from corn ears or reared on corn kernels in the dough stage. Although the bean-fed larvae became as large as those fed on corn, they produced smaller pupae. These larvae did not dig so deeply into the soil as did corn feeders, and they hibernated in smaller numbers, since most of the moths emerged in the fall, even from larvae that had entered the soil much later in the season than usual. Information on this subject is summarized in table 6. The bean-fed larvae also developed more slowly than those fed on corn kernels, as shown in table 7. The information obtained seems to indicate that the bean pods were a less satisfactory food for earworms than were corn kernels and resulted in individuals of less vigor which seemed incapable of digging as deeply into the soil. The shallowness of the burrows and consequent higher temperatures to which they

were probably subjected may have been the reason why a much greater percentage of the individuals that fed on bean pods emerged in the fall.

TABLE 6.—*Comparative season of emergence of moths from larvae of the corn earworm fed on green string bean pods and larvae fed on corn ears, Chatham County, Ga., 1931 and 1932*

Food of larvae	When larvae entered the soil	Cages	Larvae	Pupated	Average depth of pupae below surface of soil	Moths emerged			
						During fall		During spring	
		Number	*Number*	*Number*	*Inches*	*Number*	*Percent*	*Number*	*Percent*
Green pods of string beans (reared larvae).	Sept. 22 to 25, 1931.	3	300	240	2.64	212	70.67	10	3.33
Do	Oct. 6 to 22, 1932.	3	325	324	2.71	171	52.61	46	14.15
Corn ears (collected larvae)	Sept. 1 to 6, 1931.	4	400	361	4.84	43	10.75	95	23.75
Do	Aug. 28 to Sept. 3, 1932.	4	400	400	4.06	109	27.25	156	39.00

TABLE 7.—*Comparative rate of development of corn earworms fed on corn kernels and larvae fed on string bean pods. Chatham County, Ga., 1931 and 1932*

Food of larvae	Year	When larvae were reared	Larvae installed	Average period from hatching to entering soil	Moths emerged	Average period from hatching to moth emergence
			Number	*Days*	*Number*	*Days*
Corn kernels in dough stage	1930	August	190	13.6	150	27.8
Do	1931	do	250	13.8	204	31.1
Green pods of string beans	1931	September	300	21.5	212	39.3
Do	1932	do	325	20.1	171	47.6

TIME OF YEAR

The depth to which larvae dug into the soil, and, consequently, the depth at which pupae were recovered, increased slightly on an average, from May 15 to August 14, and from August 15 to September

TABLE 8.—*Average depth of corn earworm pupae below the surface of the soil during four periods of the years 1930 to 1931, Chatham County, Ga.*

Period when larvae entered the soil	Average depth of the stated number of pupae during 3 years						Average depth for the 3-year period
	1930		1931		1932		
	Pupae	Average depth	Pupae	Average depth	Pupae	Average depth	
	Number	*Inches*	*Number*	*Inches*	*Number*	*Inches*	*Inches*
May 15 to June 14			204	3.37	91	3.23	3.33
June 15 to July 14	61	3.00	214	3.49	193	3.52	3.44
July 15 to Aug. 14	230	3.33	292	3.13	189	3.90	3.47
Aug. 15 to Sept. 14	377	4.89	567	4.94	590	3.92	4.48
Mean of the average depths during the stated periods		3.08		3.73		3.66	3.68

14 it increased sharply. Larvae that entered the soil during the latter period dug burrows that averaged more than an inch deeper than those of any other period of the year. Since during the period August 15 to September 14 pupae began to hibernate in larger numbers, it seems probable that the greater depth to which larvae dug is related to the urge to hibernate. Data on average depths below the surface of the soil at which pupae were recovered during four periods of each year from 1930 to 1932, inclusive, are summarized in table 8.

EMERGENCE OF MOTHS

The time of emergence of moths was found in general to depend on when the larvae dug into the soil, but three distinct types of emergence were recognized—immediate, delayed within the current year, and delayed until the following year. Until the middle of August most moths emerged after a period of from 11 to 15 days from the time the larvae entered the soil. From May to August, inclusive, however, pupae from which moths had failed to emerge at the usual time were often found. Moths emerged from many of these pupae during the same year in which the larvae entered the soil, after a resting period of as long as 3 months. Other resting pupae entered hibernation. Moths from most of the pupae that entered the soil as larvae later than the middle of August emerged the following spring and summer.

Immediate Emergence

Since the dates when larvae entered the soil and the dates on which moths emerged were known, the average duration of the period spent underground could be calculated. During May, August, and September, for the promptly emerging individuals, this period averaged approximately 2 weeks, but in June and July, while the soil was uniformly warmer, it averaged about 11 days. A summary of the duration of this period for each month, from May to September, inclusive, is given in table 9. The proportion of individuals that emerged as moths of one brood, after a usual pupal duration, ranged from 70.92 percent of those that entered the soil as larvae during July to 10.88 percent of those that entered the soil as larvae during September.

Table 9.—*Duration of the period from the dates corn earworms entered the soil to the dates when moths emerged during 5 months, 1930 to 1932, inclusive, in Chatham County, Ga.*

Month during which larvae entered soil	Years	Cages	Total larvae	Immediate emergence	Average period from dates larvae entered soil to emergence
	Number	*Number*	*Number*	*Percent*	*Days*
May	2	6	550	56.36	15.14
June	2	5	450	65.11	11.09
July	3	7	650	70.92	11.82
August	3	12	1,150	25.30	14.02
September	2	8	800	10.88	14.74

Delayed Emergence

Although most of the larvae that entered the soil at any time during the growing season except the last 2 weeks of August and all of September produced moths in from 11 to 15 days in a single brood, there were usually found among them a number of pupae that delayed their emergence and were potential hibernators. The percentage of these delayed individuals that were found in experiments in which larvae entered the soil during four periods from May to September are given in table 10.

TABLE 10.—*Emergence of moths or occurrence of resting pupae of the corn earworm from larvae that entered the soil during four periods of the active season. Chatham County, Ga., 1930–31 and 1932–33, inclusive*

When larvae entered the soil	Cages observed for emergence the same year				Cages examined for resting pupae before winter of the first season				Cages observed for moth emergence the year following			
	Cages	Larvae introduced	Moths emerged		Cages	Larvae introduced	Pupae rested		Cages	Larvae introduced	Moths emerged	
	Number	*Number*	*Number*	*Percent*	*Number*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Number*	*Percent*
May 15 to June 14	4	350	210	60.00	3	250	56	22.40	1	100	0	0
June 15 to July 14	6	550	350	63.64	5	450	24	5.33	1	100	0	0
July 15 to August 14	8	750	465	62.00	7	650	56	8.62	1	100	27	27.00
August 15 to September 14	18	1,750	327	18.69	4	350	172	49.14	14	1,400	438	31.29

Of the larvae that developed in corn ears and whose pupae delayed transformation, several emerged as moths after a resting period during the same season. Information on the occurrence of such individuals is given in table 11.

TABLE 11.—*Delayed emergence of corn earworm moths during the same years that larvae had entered the soil. Chatham County, Ga., 1930 to 1932, inclusive*

When larvae entered the soil	Food of larvae	Larvae	Individuals delayed in emergence	Time after larvae entered the soil that delayed emergence occurred		
				Least	Greatest	Average
		Number	*Percent*	*Days*	*Days*	*Days*
May 15 to June 14	Corn kernels	200	4.5	31	94	61.9
June 15 to July 14	do	100	6.0	28	107	66.7
July 15 to Aug. 14	do	200	0			
Aug. 15 to Sept. 14	do	1,600	.9	28	71	35.9
May 27 to June 5	Bean pods	100	16.0	32	57	38.4
Sept. 22 to Oct. 1	do	300	0			
Oct. 2 to Oct. 22	do	325	.6	46	48	47.0

The evidence seems to show that, regardless of the time larvae entered the soil, some of the resulting pupae rested, but that from some of these individuals moths emerged during the same year. Since from May to September larvae were constantly entering the soil to pupate, it is probable that some of the resulting pupae were continually being delayed in emergence, and a few moths were continually emerging from such pupae. It seems possible that this delay in development of pupae was a safeguard of nature to enable the species

to survive periods when the developing forms might be exterminated or reduced in numbers by such causes as long periods of adverse weather, or epidemics of disease.

Emergence Following Hibernation

As shown in table 12, the earliest date on which a moth was observed to emerge from hibernation was April 2, 1932, and the latest date on which a moth emerged from a hibernated pupa was July 27, 1933. For the 3-year period this was a spread of 116 days, or almost 4 months. The periods when moths which fed as larvae on corn kernels or green pods of string beans emerged from hibernation during the years 1931 to 1933 are summarized in table 13.

Table 12.—*Time and rate of emergence of moths from pupae that had hibernated in soil in outdoor cages, Chatham County, Ga., 1931–33*

Year	Emergence		Moths emerged				Percentage of days on which moths emerged				
	Dates	Period	Total	Emergence per day			April	May	June	July	Entire period
				Minimum	Maximum	Average					
		Days	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1931	May 1 to July 23	84	180	0	8	2.25	.....	90.3	96.7	26.1	75.0
1932	Apr. 2 to June 27	87	125	0	6	1.44	27.6	80.6	37.0	.....	49.4
1933	Apr. 18 to July 27	101	202	0	10	2.00	46.2	83.9	83.3	22.2	62.4
	Average	91	.....	.....	.....	1.90	.....	.....	.....	.....	62.1

Table 13.—*Period of emergence of corn earworm moths from pupae that had hibernated in soil in outdoor cages, the larvae of which fed on corn kernels or green pods of string beans during different periods of the years 1930 to 1932, inclusive, Chatham County, Ga.*

Season and date when larvae began to enter soil	Larvae installed	Source of larvae	Food of larvae	Moths emerged from hibernation	Time after larvae began to enter the soil to emergence of moths			Duration of the emergence period
					First moth	Last moth	Average	
1930–31	*Number*			*Number*	*Days*	*Days*	*Days*	*Days*
Aug. 11	100	Collected	Corn kernels	27	265	323	291.2	59
Aug. 22	100	do	do	36	255	328	286.1	74
Sept. 1	200	do	do	61	244	318	272.6	75
Sept. 12	200	do	do	65	231	314	264.9	84
Entire period	600			189	231	328	275.2	84
1931–32								
Aug. 20	100	Collected	Corn kernels	20	226	296	267.9	71
Sept. 1	400	do	do	95	221	300	263.3	80
Sept. 22	300	Reared	Green string bean pods.	10	227	269	244.2	43
Entire period	800			125	221	300	262.5	80
1932–33								
Aug. 28	400	Collected	Corn kernels	156	233	333	276.9	101
Oct. 2	325	Reared	Green string bean pods.	46	190	251	233.3	62
Entire period	725			202	190	333	267.0	101

In 1932 the period of emergence was approximately a month earlier than in 1931, but smaller numbers of moths emerged than in either of the other years studied. During the 3 years the average period over which emergence occurred was 91 days.

The long periods during which moths emerged from hibernation resulted in few appearing on any one day. On 35.29 percent of the days covered by this period none emerged, and the daily emergence rate of greatest frequency was 1, which occurred in 22.79 percent of the instances. The greatest number of moths emerging on 1 day was 10, which occurred once, or in 0.37 percent of the instances. The average emergence of moths from hibernation for the 3 years was 30.7 percent of the larvae that entered the soil during the preceding year. In 1931 emergence ranged from 23 to 38 percent in 6 cages, or an average of 31.5 percent; in 1932, from 18 to 28 percent in 5 cages, or an average of 23; and in 1933, from 27 to 51 percent in 4 cages, or an average of 39.

No moths emerged the following year from cages in which larvae entered the soil between May 15 and July 14, although delayed, or resting, pupae were found in such cages when they were examined within the season during which the larvae had developed. From July 15 onward increasing percentages of pupae rested and entered hibernation, and as a consequence increasing percentages of moths emerged during the following spring and summer from cages in which larvae entered the soil during these periods.

Relation of Depth of Pupae in Soil to Emergence

The data previously presented have shown that throughout the growing season, whenever larvae entered the soil, they dug to varying depths below the surface. The extreme variation observed was from less than 1 to more than 10 inches. Variation occurred even among larvae hatching from eggs laid by a single moth, developing on the same food, becoming full grown at the same time, and entering soil of uniform moisture and texture in the same cage.

A well-defined tendency toward delay in emergence of adults from pupae resting at the greatest depths below the surface was observed. During four periods of the years 1930 to 1932, inclusive, the average depth of pupae from which moths emerged immediately ranged from 2.7 to 3.3 inches. During the same periods the average depth of pupae from which moths did not emerge immediately ranged from 4.8 to 5.7 inches. There was no specific depth, however, separating individuals that would emerge immediately from those that would delay their emergence. Information on this subject is summarized in table 14.

The depth at which pupae rested below the surface of the soil therefore was a factor, possibly the most important one, governing whether pupae would emerge immediately during the same year in which larvae entered the soil, or whether emergence would be delayed and the pupae would probably hibernate.

TABLE 14.—*Depth of pupation of the corn earworm in relation to the time when larvae entered the soil and to the time when moths emerged during 4 periods of the years 1930 to 1932, inclusive, Chatham County, Ga.*

INDIVIDUALS THAT EMERGED AS MOTHS THE SAME SEASON

Dates when larvae entered the soil	Total larvae [1]	Total pupae [1] recovered	Percentage of pupae found at the stated depths in inches below the surface of the soil											Pupae that did not hibernate		Pupae that hibernated		Average depth of pupae
			1 or less	1.1–2	2.1–2	3.1–4	4.1–5	5.1–6	6.1–7	7.1–8	8.1–9	9.1–10	10.1–11	Total	Proportion of the total recovered	Total	Proportion of the total recovered	
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Inches*
May 15 to June 14	250	211	0.65	21.93	47.09	23.87	5.81	-------	0.65	-------	-------	-------	-------	155	73.5	-------	-------	2.7
June 15 to July 14	450	345	.31	13.39	36.45	26.48	15.27	5.92	1.87	0.31	-------	-------	-------	321	93.0	-------	-------	3.3
July 15 to Aug. 14	550	455	.75	16.54	40.10	19.80	12.78	7.77	2.01	.25	-------	-------	-------	399	87.7	-------	-------	3.2
Aug. 15 to Sept. 14	350	266	1.06	19.15	42.55	14.89	15.96	6.38	-------	-------	-------	-------	-------	94	35.3	-------	-------	3.0
Total or average	1,600	1,277	.62	16.62	40.25	22.19	12.78	5.78	1.55	.21	-------	-------	-------	969	75.9	-------	-------	.1

INDIVIDUALS THAT HIBERNATED AS PUPAE

May 15 to June 14	250	211	-------	-------	3.57	12.50	51.78	21.43	5.36	3.57	1.79	-------	-------	-------	-------	56	26.5	4.8
June 15 to July 14	450	345	-------	-------	-------	16.67	33.33	33.33	8.33	8.33	-------	-------	-------	-------	-------	24	7.0	5.1
July 15 to Aug. 14	550	455	-------	-------	-------	10.71	25.00	26.79	21.43	10.71	1.79	3.57	-------	-------	-------	56	12.3	5.7
Aug. 15 to Sept. 14	350	266	-------	-------	5.82	12.79	33.72	26.75	13.95	3.49	1.16	1.16	1.16	-------	-------	172	64.7	5.2
Total or average	1,600	1,277	-------	-------	3.90	12.66	35.40	26.29	13.31	5.19	1.30	1.30	.65	-------	-------	308	24.1	5.2

[1] Data on pupae recovered in cages, the soil of which was examined the same year in which larvae developed, were separated into 2 groups according to whether individuals had emerged the same season or had delayed emergence to enter hibernation. The 2 sections of this table, therefore, refer to identical series of cages.

DISCUSSION

The information obtained during this investigation showed that resting pupae were continuously present in the soil in the area described. Long before the last moths had emerged from hibernation some of the pupae of larvae that had entered the soil in May had begun to rest in the soil. Although some of these pupae that began to rest early in the season emerged later in that same year, others continued in the resting condition and entered hibernation the following fall although, in these experiments, none of these survived the winter. It seems remarkable that such pupae could remain inactive throughout the four warmest months of the year, from June to September, while individuals in active stages of development were passing through four generations.

The factors which caused larvae to dig shallow burrows, such as wet or friable soil, or inferior food such as green pods of string beans, which resulted in individuals of less vigor, tended indirectly to produce pupae that emerged within 11 to 15 days. On the other hand, factors that caused larvae to dig deep burrows, such as dry or firm soil, or food such as corn kernels, especially kernels in the dough stage of development, produced pupae that tended to delay emergence and that often hibernated.

But even when all such factors were controlled, much variation occurred in the depth to which individual larvae burrowed. Since larvae probably entered the soil in the field every day from May to September, inclusive, some of which transformed to moths at once, some of which delayed emergence until later in the same season, and some of which emerged over a period of from 3 to 4 months in the following spring and summer, it was likely that moths emerged each day during the growing season. This resulted in a continuous occurrence of moths capable of depositing eggs on corn or other plants, so that whenever these crops were planted or were in stages of growth attractive to the insects they were attacked rather uniformly. The pupation and emergence habits of the insect probably are an important advantage to it, since, regardless of what disaster might befall the active stages in any season of the year, the resting pupae in the soil would be capable of preserving the species from complete destruction. Their continuous presence in the soil probably is largely responsible for the remarkable uniformity with which the active stages of the earworm occur in the southeastern part of the United States throughout the entire growing season.

The results of this investigation indicate that several measures might be taken to protect field corn against injury by earworms. Previous studies [3] showed that early-planted corn in Virginia was less injured by earworms than was later corn, and that the yield was higher. This was also observed to be true in southeastern Georgia. The probable reason is that early-planted corn is attacked by the progeny of the relatively few moths that emerge from hibernation early in the season, whereas later corn is attacked by the progeny of the moths that emerge from hibernation later and, in addition, by the increasing population developed during the current season.

[3] PHILLIPS, W. J., and BARBER, G. W. EARWORM INJURY IN RELATION TO DATE OF PLANTING FIELD CORN IN CENTRAL VIRGINIA. Va. Agr. Expt. Sta. Tech. Bul. 55, 15 pp., illus. 1934.

The present studies have shown that larvae maturing in the earlier part of the growing season did not burrow so deeply into the soil to prepare quarters for the pupae, and that a greater proportion of them produced moths the same season than was the case with larvae that matured late in the season. The looser soil of the early season was less favorable to survival and hibernation of the pupae than was the more firmly packed soil later in the season. As a consequence, few of the individuals that matured in early corn remained in the soil as potential hibernators. It seems not unreasonable to expect that if all the field corn in an area could be planted early, and be followed by crops that are less attractive to or less suitable as food plants for earworms, the overwintering population of the insect would be reduced, because most of those developed in the early corn would have emerged as moths during the current season and the comparative scarcity of suitable food plants would have been unfavorable to their progeny. This would result in the presence of a smaller population of moths early in the following season, the progeny of which would cause less damage to early planted corn than has been the case heretofore.

Frequent cultivation of the soil during the summer prevents it from becoming firmly packed, and, consequently, causes it to be less favorable for burrowing by the larvae or survival of the pupae. Plowing before April 1 destroys many of the pupae or, through disrupting the emergence burrows, prevents emergence of the moths.

SUMMARY

A study of hibernation of the corn earworm was made in Chatham County, Ga., during the years 1930 to 1933, inclusive.

The larvae were allowed to enter the soil under cages that were kept in the same locations from year to year, and the different experiments covered the same periods each year, roughly representing the incidence of the different generations. Because of overlapping generations, larvae became full grown and entered the soil to pupate continuously from the latter part of May until early in October.

Some of these individuals died as larvae or as pupae, but the rate of survival ranged from 44 to 88 percent, and averaged 75 percent in cages examined the same year in which larvae entered the soil, and from 30 to 80 percent, or an average of 51 percent, in cages examined the following summer after hibernation. Parasitization was very low.

The depth to which larvae burrowed below the surface of the soil, and at which pupae were recovered, ranged from less than 1 to more than 10 inches. This was influenced by several factors. Larvae dug deeper in dry soil or in soil that was well packed. Those that had developed on the green pods of string beans did not go so deep as those that had developed on corn kernels. Corn-fed larvae dug much deeper from the middle of August onward than earlier in the season.

Three types of emergence were recognized—immediate, delayed within the current year, and delayed until the following year. Most of the adults from larvae that entered the soil from May to the middle of August emerged in from 11 to 15 days after the larvae had become full-grown. Moths from a few of these larvae emerged later, as much as 3 months after the larvae had become full-grown. Whenever larvae entered the soil some of the resulting pupae delayed emergence

and were potential hibernators. The pupae of most of the larvae that entered the soil after the middle of August hibernated. Moths emerged from these pupae from May 1 to July 23 in 1931, from April 2 to June 27 in 1932, and from April 18 to July 27 in 1933. Hibernating individuals remained in the soil from 190 to 333 days.

The variation in depth to which the larvae burrowed, and consequently at which pupae rested, evidently enables the insect to survive disasters that might befall the active stages above ground, since resting pupae were continuously present in the soil and moths were continuously emerging throughout the growing season. These facts apparently help to explain the uniformity with which the active stages of the insect occur in the southeastern part of the United States throughout the growing season.

In general, pupae located at the greatest depths in the soil did not emerge at once and often hibernated, whereas those not so deep usually emerged at once. For four periods of the 3 years mentioned the average depth of pupae that emerged at once ranged from 2.7 to 3.3 inches, or a mean depth of 3.1 inches, whereas the average depths of pupae that delayed emergence or hibernated ranged from 4.8 to 5.7 inches, or a mean depth of 5.2 inches.

It was known from previous investigations that field corn planted early in the season in Virginia was less injured by earworms and produced a greater yield than later-planted corn. The present studies indicate that few of the larvae maturing in early corn hibernated. It seems reasonable to conclude that if all field corn of an area could be planted early and followed by crops that were not attractive as food plants for earworms, the overwintering population of the insect would be reduced, and that the smaller number of earworms occurring early in the following season would cause less injury to early corn than has been the case heretofore.

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