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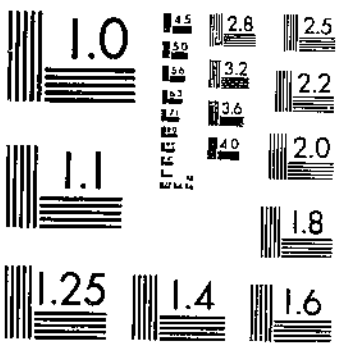

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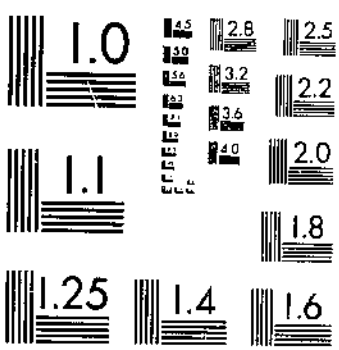

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NATIONAL BUREAU OF STANDARDS-1963 A

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Washington, D. C.

LIFE HISTORY OF THE CODLING MOTH IN THE ROGUE RIVER VALLEY OF OREGON

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CONTENTS

INTRODUCTION

This bulletin is one of a series by the Bureau of Entomology reporting life-history studies of the codling moth (*Carpocapsa pomonella* L.) in different parts of the United States. Bulletins of this series [1] have already been published reporting studies in Michigan, the Santa Clara Valley of California, the central Appalachian region, Maine, the Ozarks in Arkansas, the Pecos Valley of New Mexico, the Grand Valley of Colorado, the Yakima Valley of Washington, Delaware, and northern Georgia. The object of the work in each case has been to determine the correlation and the differences in the occurrence of the stages under varying seasonal conditions. From these studies a greater knowledge of the necessary control operations can be obtained.

The studies reported in this bulletin were carried on in the Rogue River Valley of Oregon, at Medford, during the years 1918 to 1922, inclusive. The work was in charge of the senior writer, assisted by R. Bruce McKeown, in 1918, 1919, and part of 1920; by Lorena

[1] The Codling Moth in the Ozarks, Bur. Ent. Bul. 80, part 1, 1909; Life-History Studies on the Codling Moth in Michigan, Bur. Ent. Bul. 115, part 1, 1912; Life History of the Codling Moth in the Santa Clara Valley of California, Bur. Ent. Bul. 115, part 3, 1913; Studies of the Codling Moth in the Central Appalachian Region, Dept. Bul. 189, 1915; Life History of the Codling Moth in Maine, Dept. Bul. 252, 1915; Life History of the Codling Moth in the Pecos Valley of New Mexico, Dept. Bul. 429, 1917; Life History of the Codling Moth in the Grand Valley of Colorado, Dept. Bul. 982, 1921; Life History of the Codling Moth in the Yakima Valley of Washington, Dept. Bul. 1235, 1924; Life History of the Codling Moth in Delaware, Tech. Bul. 42, 1928; Life History of the Codling Moth in northern Georgia, Tech. Bul. 90, 1929.

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Stratton in 1919, 1920, and 1921; and by the junior writer in 1922. The whole project was under the supervision of A. L. Quaintance, in charge of deciduous-fruit insect investigations. The junior writer, assisted by L. C. McAlister, prepared the data for publication and is largely responsible for the report in its present form. Many of the other reports cover studies made during a period of two or three years, whereas the investigations covered in this bulletin are for five seasons. On account of the large mass of data which has accumulated it has been considered advisable to omit the large tables usually found in reports of this kind and concentrate the more important data into graphs and short tables.

THE ROGUE RIVER VALLEY OF OREGON

The Rogue River Valley is located in Jackson County, Oreg., the southern boundary of which joins the northern boundary of California, 50 miles inland from the Pacific Ocean. The valley is surrounded on all sides, except where the Rogue River cuts its way westward toward the Pacific, by spurs of the Cascade Mountains and the coast range. It has an area of approximately 60,000 acres, and lies at an average elevation of about 1,400 feet, the elevation at Medford. Of the above area, about 30,000 acres are under cultivation, one-half of which is planted to pear and apple orchards. While there are larger pear-producing areas in the United States than the Rogue River Valley, this is one of the most concentrated. Annual shipments of pears and apples from this section average 3,000 to 3,500 cars of pears and about 500 to 700 cars of apples.

CLIMATE

The climate is relatively dry, the average annual precipitation being 16 or 17 inches, very little of which comes during the growing season. Moisture is provided by means of irrigation systems, of which there are a number, the water being supplied by various mountain streams. Little water is taken from the Rogue River proper, since it crosses only the extreme lower end of the valley. The day temperatures during the summer season are often high, while the nights are usually comparatively cool. (Table 1.)

TABLE 1.—*Climatological data*[1] *for Medford, Oreg., 1918 to 1922, inclusive*

Month	Mean temperature						Precipitation					
	1918	1919	1920	1921	1922	Average for five years	1918	1919	1920	1921	1922	Average for five years
	°F.	°F.	°F.	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	41.2	39.4	37.2	39.1	33.6	38.10	2.17	2.44	0.42	3.12	1.76	1.96
February	41.9	40.8	39.8	42.8	39.2	40.90	2.64	4.30	.33	3.35	2.33	2.52
March	46.6	46.3	43.5	47.5	43.6	45.50	1.69	1.76	1.44	1.06	1.84	1.56
April	51.7	52.6	48.4	50.4	48.1	50.24	.39	1.15	.99	.75	.61	.78
May	54.7	57.4	56.2	56.0	57.8	56.42	.54	.03	.96	2.47	1.22	1.04
June	70.6	62.9	63.8	66.0	67.6	66.18	.01	T.	1.81	.10	.56	.50
July	69.8	72.8	70.2	70.6	74.6	71.60	.03	.03	.24	T.	0	.06
August	68.8	71.7	72.8	71.0	68.7	70.60	.25	.03	.36	0	T.	.13
September	67.0	62.0	62.6	61.0	65.4	63.60	1.57	.66	.99	.04	.50	.77
October	55.2	48.2	50.6	56.2	54.2	52.88	1.57	.60	1.20	.88	1.48	1.14
November	41.6	39.6	44.3	46.2	41.0	42.54	2.29	1.87	4.27	3.54	1.35	2.66
December	36.1	33.6	40.6	36.6	38.2	37.02	1.44	2.57	3.43	.94	5.36	2.75
Annual mean or total	53.7	52.3	52.5	53.6	52.7	52.96	14.69	15.14	16.33	16.21	17.01	15.87

[1] From U. S. Weather Bureau Reports.

CLIMATOLOGICAL DATA FOR THE STATE OF OREGON, 1918–1922

The following statements from the United States Weather Bureau's reports [2] for the State as a whole agree very closely with the climatological data for Medford; they are, therefore, given as a statement of the weather conditions prevailing in the Rogue River Valley for the five years 1918 to 1922, inclusive.

1918

The year was unusually warm and dry. The mean temperature was the highest recorded in Oregon in the last 14 years. June and September were the warmest months of the name on record, and over a large part of the State the summer as a whole was the warmest on record. The average precipitation was the least experienced in Oregon since state-wide records have been kept.

1919

The year as a whole was only slightly cooler than usual, but the minimum temperatures were quite generally the lowest on record. * * * The drought that prevailed from the latter part of April to the first week in September was the most severe on record.

1920

The year as a whole did not depart materially from the normal in any weather element. * * * January, February, and May were the driest months of the name on record. * * * The temperature during the spring was below normal. * * * April * * * was the coldest April on record. * * * Throughout most of the summer the temperature was seasonable.

1921

The year, as a whole, was slightly milder and wetter than usual, but no new state-wide records were established. March was rather mild and dry, but the preceding winter months had been unusually wet. The summer months were about normal. Widespread killing frosts in the second week in September caused some damage to tender crops.

1922

The year, as a whole, was unusually dry, and somewhat colder than usual. Only one year since state-wide records have been published has been drier. Eight of the 12 months had less than the normal precipitation, and July was the driest month of the name on record. The deficiency in temperature was most pronounced in the winter, early spring, and late fall, while in the late spring, early sumer, and early fall some unusually high temperature was experienced. * * * The 5-month period, December, 1921, to April, 1922, inclusive, was the coldest of record. * * * Vegetation * * * was unusually late in starting in the spring. A heavy drop of fruit resulted from unfavorable weather during the blossoming period. Summer came suddenly in the last week in May. At many stations the maximum temperature for the month was the highest May temperature in many years. June, July, and September were unusually warm and dry. Mild weather continued until well into October.

EXPLANATION OF TERMS

Certain definite terms, adopted by the Bureau of Entomology and used in its other publications on the life history of the codling moth, have been used in this bulletin. The more important of these are as follows:

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[2] These statements are quoted or abstracted from Climatological Data, Oregon Section, published by the Weather Bureau of the U. S. Department of Agriculture.

The term "generation" is here used to include all of the consecutive stages of the codling moth throughout the season, starting with the egg and ending with the adult or moth. Thus the first eggs to be laid (those deposited by the first moths of the season) would start the first generation; these and the resulting larvae, pupae, and moths would belong to this generation. The eggs deposited by the moths which belong to the first generation start the second generation, to which also belong the resulting larvae, pupae, and moths, and so on.

The term "brood" as used in this bulletin is applied to any stage of the codling moth which may belong to a specific generation or to an unknown generation. For example, the eggs, larvae, pupae, and moths which belong to the first generation are called first-brood eggs, larvae, pupae and moths.[3]

The larvae which pass the winter include all the nontransforming larvae of the first and second broods, and, in the Rogue River Valley, all the larvae of the third brood. The specific generation to which each of these individuals belongs can not be determined unless they have been reared. The term "generation," therefore, can not properly be used to include the various stages of their transformations; they are simply called "wintering" or "spring-brood" larvae, and the pupae and moths into which they transform are designated "spring-brood" pupae and moths.

As mentioned previously and explained later, the larvae which hatch from the eggs deposited by the second brood of moths do not transform into pupae and moths the same season as hatched, but pass the winter in the larval stage. Hence there is, in the Rogue River Valley, what might be called a partial or incomplete third generation. However, these eggs and larvae are known as third-brood eggs and larvae.

The "life cycle" of a generation includes the time from the deposition of the egg to the emergence of the moth of the same generation.

The "complete life cycle" extends from the time of deposition of the egg of one generation to the deposition of the egg of the next generation, and, strictly speaking, should apply to the female sex only.

The seasonal-history studies begin with the wintering or spring-brood larvae which transform to pupae of the spring brood and from which issue the moths of the spring brood.

The moths of the spring brood deposit eggs of the first brood, which, after their incubation period, result in the larvae of the first brood. Some of these remain in the larval stage until the following spring, while most of them transform successively into pupae and moths of the first brood.

The moths of the first brood deposit the eggs of the second brood, which, after their incubation period, produce larvae of the second brood. Some of these, like some of the first-brood larvae, are wintering individuals, while the others transform and become successively the pupae and moths of the second brood.

The moths of the second brood deposit the eggs of the third brood. In the Rogue River Valley all the larvae of this brood pass

[3] It thus happens that the first moths to appear in the spring are not "first-brood" moths, but "spring-brood" moths, which is technically correct, but greatly confusing to the orchardist.

the winter and comprise part of the spring brood of pupae and moths the following season.

Wintering larvae or larvae of the spring brood (spring-brood larvae) include: All of the nontransforming larvae of the first and second broods and all of the larvae of the third brood of the preceding season.

Pupae of the spring brood (spring-brood pupae) include: All of the pupae from the spring-brood or wintering larvae.

Moths of the spring brood (spring-brood moths) include: All of the moths from the pupae of the spring brood.

The first generation includes:

(1) The eggs of the first brood (deposited by spring-brood moths).
(2) The larvae of the first brood:
  (*a*) Transforming first-brood larvae.
  (*b*) Wintering first-brood larvae.
(3) The pupae of the first brood.
(4) The moths of the first brood.

The second generation includes:

(1) The eggs of the second brood.
(2) The larvae of the second brood:
  (*a*) Transforming second-brood larvae.
  (*b*) Wintering second-brood larvae.
(3) The pupae of the second brood.
(4) The moths of the second brood.

The third generation (not complete in the Rogue River Valley) includes:

(1) The eggs of the third brood.
(2) The larvae of the third brood, all of which are wintering individuals.

SEASONAL HISTORY STUDIES

The methods used in the study of the life history of the codling moth were similar in most respects to those used by the Bureau of Entomology at other places and need not be repeated here. A large outdoor insectary was used in conducting most of the studies. Field observations were made daily as a check on the development of the moth under insectary conditions. The very first activity among the wintering codling-moth larvae is the rebuilding of the cocoon to form an exit tube which permits the moth to free itself more readily. This change in the cocoon is not reported in this bulletin. The first activity recorded was the pupation of the wintering larvae.

Great care was taken to have large numbers of individuals from which to draw conclusions. The number of individuals for each stage is given either in the graphs showing the activity of the brood or is stated in the final summary (p. 26).

PUPAE OF THE SPRING BROOD

Time of pupation.—The recorded time of the pupation of the spring brood is shown graphically for each season in Figure 1. The graphs show the results of daily observations. The larvae kept in cocooning racks were gathered from wintering field material the previous fall, and the records were taken before 9 a. m. daily. The very first pupation was not observed during 1919 and 1921, but from the observations of the other three years it will be noted that there

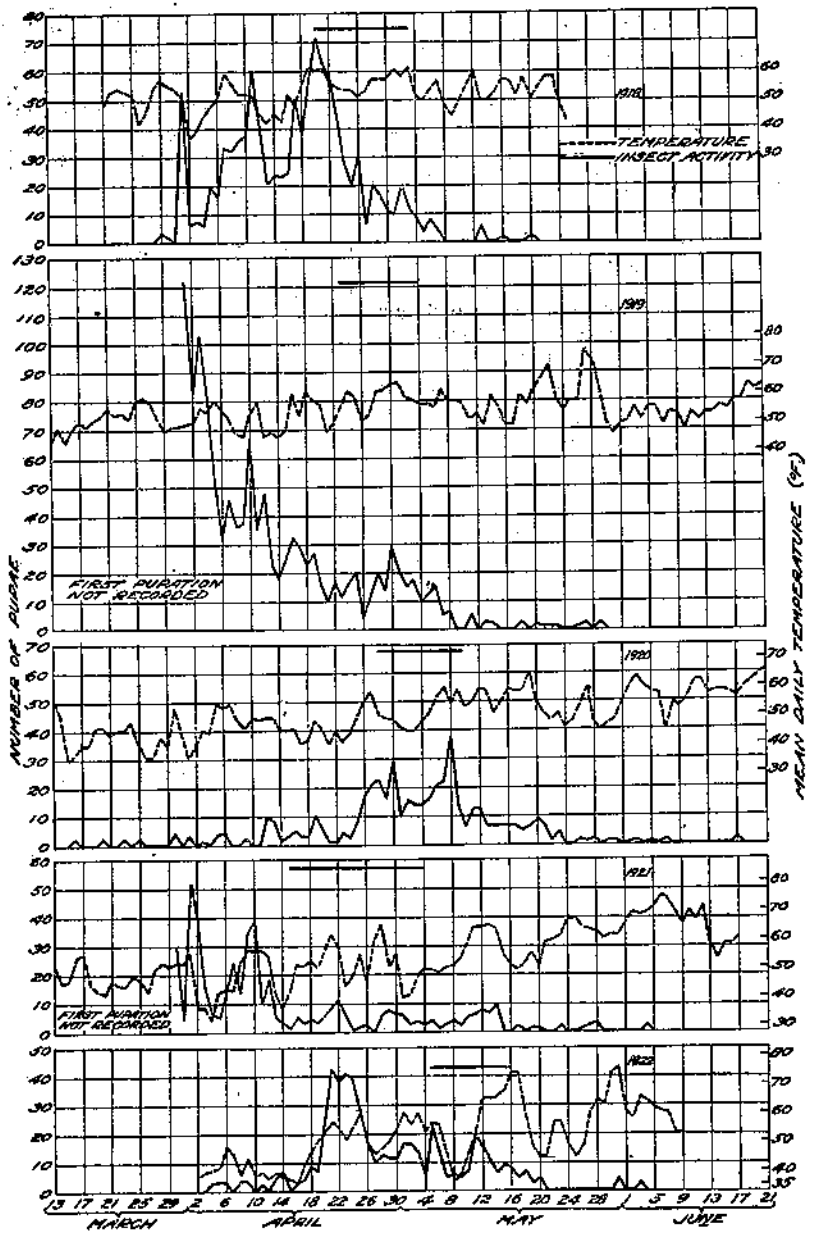

FIGURE 1.—Time of pupation of spring-brood pupae of the codling moth, Medford, Oreg. The short, heavy, horizontal lines cover the blooming periods of the Yellow Newtown apple

was considerable variation in the time the first larva transformed to the pupal stage. The earliest larva to pupate was recorded on March 16, 1920, and the latest one on June 17, 1920. The date of maximum pupation is just as variable as the time the first and last pupation occurred. The period of pupation ranged from a minimum of 53 days in 1918 to a maximum of 94 days in 1920. It is believed that pupation generally begins during the last part of March or the first part of April.

Length of pupal stage.—The maximum length of the pupal stage for the spring brood varied from 35 days in 1918 to 60 days in 1920. The average length of this stage varied from 25.56 to 43.8 days, and the minimum varied from 14 days in 1920 to 25 days in 1921. A total of 2,095 pupae were observed during the five years in obtaining the above records. The length of time for the pupal stage is given in Table 2.

TABLE 2.—*Length of the pupal stage of 2,095 pupae of the spring brood of the codling moth, Medford, Oreg.*

Year	Individuals	Length of pupal stage		
		Minimum	Average	Maximum
	Number	*Days*	*Days*	*Days*
1918	340	19	26.04	35
1919	623	24	35.42	45
1920	418	14	31.80	60
1921	302	25	43.80	56
1922	412	15	25.56	53

MOTHS OF THE SPRING BROOD

Time of emergence.—The emergence of the spring-brood moths is largely dependent upon the temperature and atmospheric conditions and is shown in Figure 2. The very earliest moth to emerge in each of the five years was recorded, as well as the number of moths during the entire emergence period. The earliest moth issued on April 18, 1919; in 1920 the first moth was recorded on May 15, or about 28 days later. Moth emergence took place over a considerable period of time. Most years the emergence began during the latter part of April and continued into the latter half of June. The shortest period of moth emergence was in 1921 when it covered a period of 35 days, whereas the longest period of moth emergence occurred in 1922 over a period of 61 days. The period of maximum emergence is just as variable. In the graph the time of the blooming period of the Yellow Newtown apple is shown by the straight heavy line.

Oviposition by moths of the spring brood.—The average number of days before oviposition occurred varied between 6.4 days in 1918 and 3.12 days in 1922. The maximum period before oviposition for the five years was 16 days and the minimum was 1 day. Although the moths of this brood usually began depositing their eggs within from 3 to 6 days after emergence, the maximum oviposition occurred from 7 to 10 days after emergence. The maximum period before the greatest oviposition was 26 days. Some moths continued to oviposit for a period of 37 days after emergence; the average oviposition period ranged from 12.81 to 20.2 days.

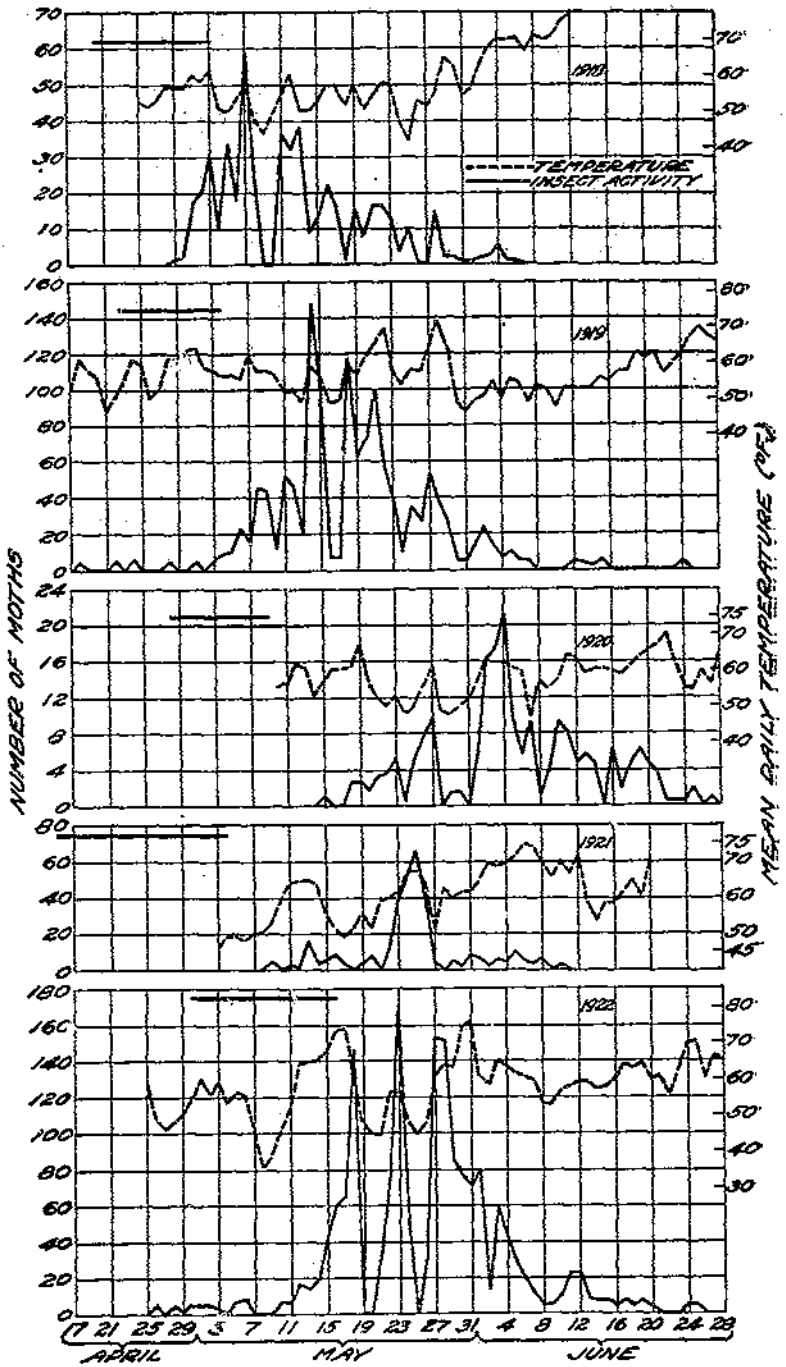

FIGURE 2.—Time of emergence of moths of the spring brood of the codling moth, Medford, Oreg. The short, heavy, horizontal lines cover the blooming periods of the Yellow Newtown apple

Number of eggs per female moth.—The records on the number of eggs deposited per female moth are based on the total number of eggs taken from the stock jars where all moths under observation were confined. Under these conditions it is impossible to know the number of eggs deposited by an individual moth. It is possible that some moths did not deposit any eggs during the entire period. The maximum number of eggs deposited per female moth during the five years of study was 89 in 1921, whereas the maximum number was 26 in both 1918 and 1920. The average number of eggs per female moth ranged from 6.15 in 1920 to 29.07 in 1922.

Length of life of moths.—The dead moths in the oviposition cages were removed each day; their sex was determined and their length of life computed. The results of these studies, in which 3,106 moths were observed, are as follows: The average length of life of the male moths ranged from 13.18 days to 15.24 days; that of the female moths ranged from 14.08 days to 16.61 days. The maximum length of life for a male moth was 38 days, female moth 37 days. The minimum length of life for both sexes was 1 day.

THE FIRST GENERATION

EGGS OF THE FIRST BROOD

Time of egg deposition.—The number of eggs deposited during five years is shown graphically in Figure 3. Although there is some variation in the time eggs were deposited during the years the studies were made, the first eggs were usually deposited during the early part of May. The earliest deposition occurred on May 1, 1918. The latest date of deposition was July 6, 1920. The periods of greatest deposition of first-brood eggs for the five seasons during which records were taken were as follows: 1918, May 3 to 22; 1919, May 16 to June 1; 1920, June 4 to 19; 1921, May 26 to June 12; and 1922, May 26 to June 10.

Length of incubation.—The records on length of incubation are not complete for the years 1919, 1920, and 1921, but the average for the other two years was 10.62 and 14.31 days. The maximum incubation period for the two years was 22 days and the minimum 5 days. The only year records were taken on development of red ring and black spot was in 1922. For that year the average length of time from date of deposition to appearance of the red ring was 3.37 days, maximum 7, and minimum 2 days; the average length of time from deposition to appearance of the black spot was 8.91 days, maximum 15, minimum 6 days.

LARVAE OF THE FIRST BROOD

Time of hatching.—The records of the daily hatching of eggs of the first brood over a period of five years, shown by the solid lines, with the mean daily temperatures, shown by the broken lines, are presented graphically in Figure 4. The earliest date of hatching was May 11, 1918. The latest date of first hatching was June 14, 1920, which is later than the date of maximum hatching for any other year. Possibly this can be accounted for by the low temperatures which prevailed during the first part of June that year. During the five years as a whole the period of hatching of eggs of the first

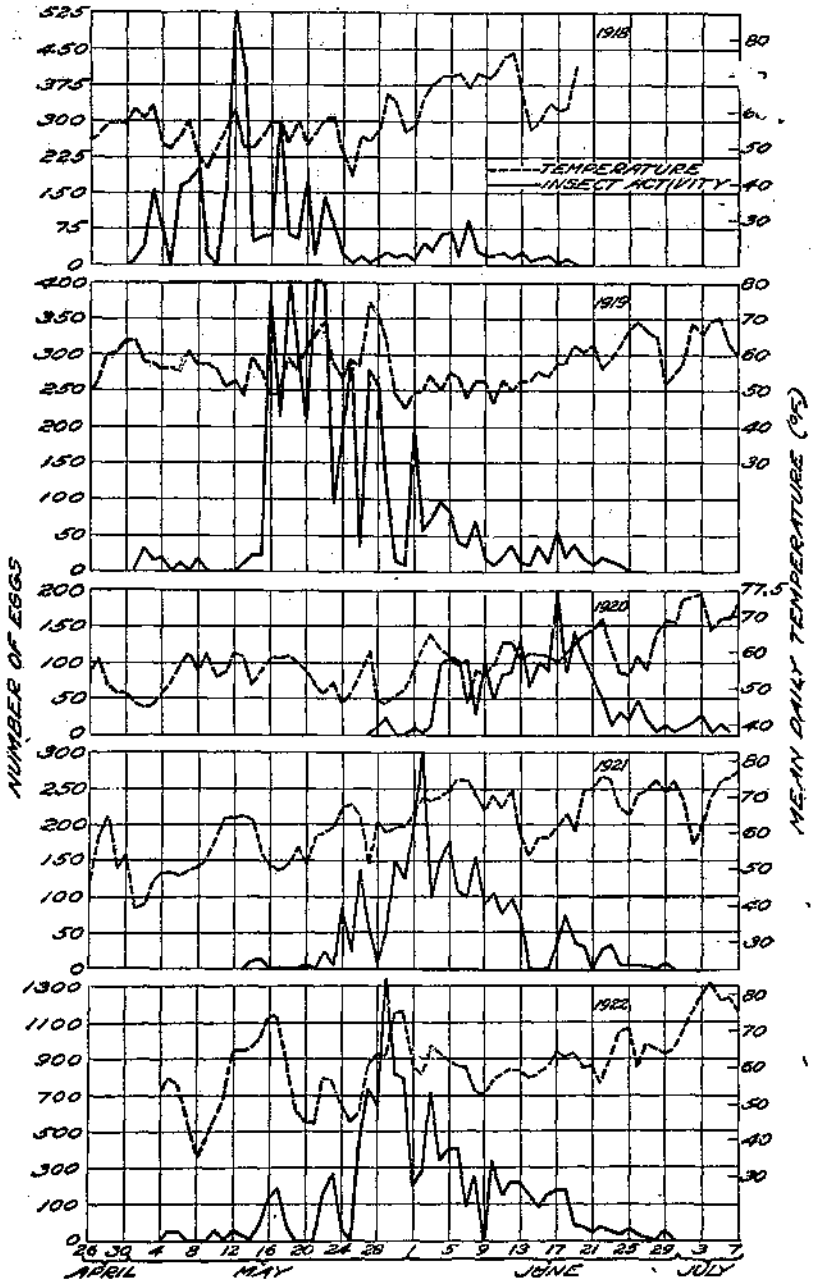

FIGURE 8.—Time of deposition of eggs of the first brood of the codling moth, Medford, Oreg.

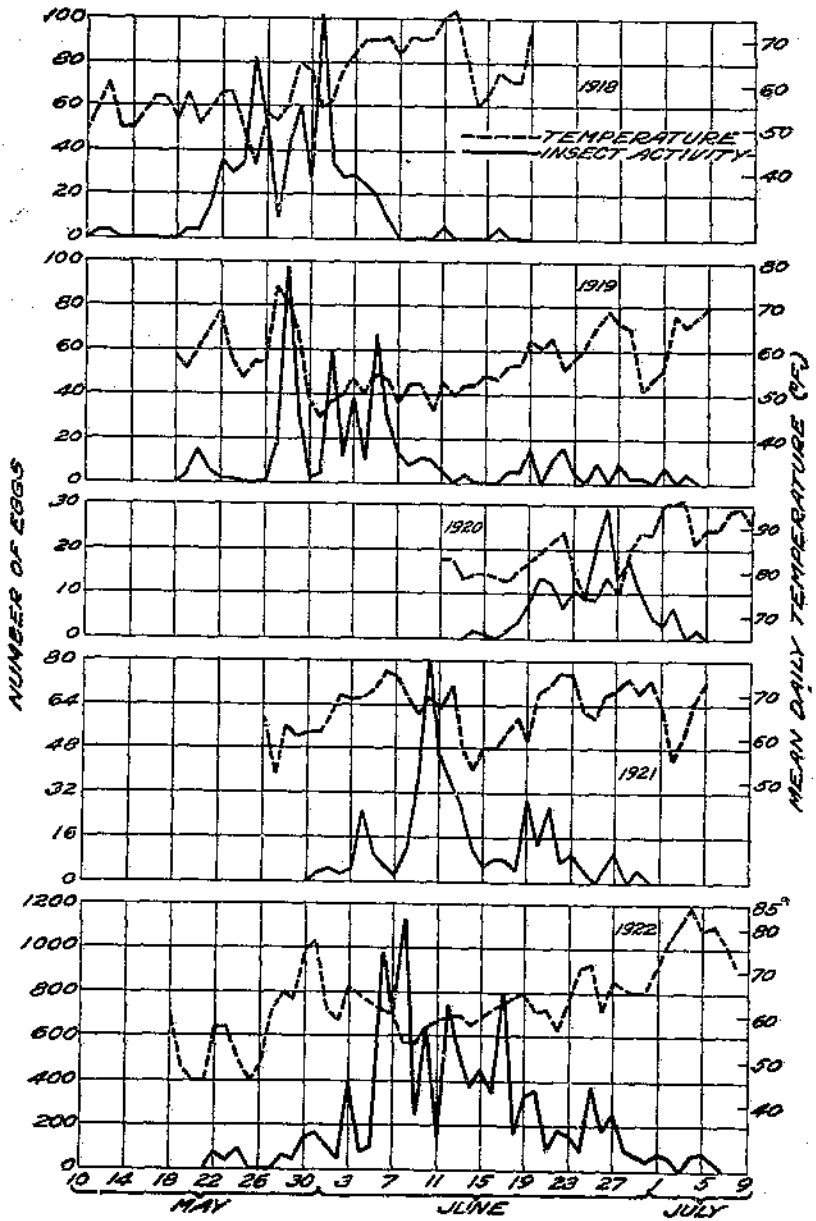

FIGURE 4.—Time of hatching of eggs of the first brood of the codling moth, Medford, Oreg.

brood extended over part of May, all of June, and part of July; in 1920 most of the hatching occurred during the latter part of June. The latest date of last hatching was July 8, 1920. The date of the earliest peak of hatching was May 28, 1919, and the date of the latest peak of hatching was June 26, 1920. The period of maximum hatching usually occurred during the last part of May and the first part of June.

Length of feeding period.—The records for the year 1921 are not complete in this connection, but for the other four years the average length of the feeding period was as follows: 1918, 20.07 days; 1919, 28.27 days; 1920, 30.6 days; and 1922, 22.43 days. The maximum feeding period ranged from 33 days in 1918 to 52 days in 1920. The shortest period of time for a larva to complete its feeding was 10 days, in 1922, while 27 days was the shortest period in 1920.

Length of cocooning period.—The cocooning period for the four years recorded varied but little. The average period ranged from 4.32 to 6.61 days. The greatest length of time spent in the cocoon before pupating occurred in 1922, with a maximum of 29 days. The shortest periods were from 2 to 4 days.

PUPAE OF THE FIRST BROOD

Time of pupation.—Figure 5 presents graphically the records for five years of daily pupation of larvae of the first brood shown by the solid lines, with the mean daily temperatures shown by the broken lines. The earliest pupation of transforming larvae of the first brood occurred June 16, 1918, and the latest took place August 10, in 1920 and 1922. In 1918 the peak of pupation was on June 19, and the period of pupation ended July 4, the earliest date of last pupation. In 1922 the period of pupation was longest, extending from June 24 to August 10. Maximum pupation occurred during June in 1918, during the first half of July in 1919 and 1922, and during the second half of July in 1920 and 1921.

Length of pupal stage.—The average length of the pupation period was about the same for each year of the five years studied. It ranged from 12.12 to 14.95 days. The maximum pupal period ranged from 17 to 31 days, the minimum from 6 to 11 days. A total of 1,446 pupae were observed during the 5-year period.

MOTHS OF THE FIRST BROOD

Time of emergence.—The earliest emergence of first-brood moths, as indicated by the solid lines in Figure 6, was recorded in 1918 on June 26. Emergence in 1922 began on July 5, being followed by July 13 in 1919, and July 15 in 1921, while the latest date on which the first moths of this brood appeared was on July 24 in 1920.

The comparatively even high temperature in 1918 resulted in an early completion of emergence for that year, and the last insect emerging was recorded on July 25, 21 days earlier than the last moths of 1919 and 1922 which appeared on August 15 of both years. In 1920, despite a late start, the last moth was recorded on August 16, and the last noted in any year was on August 17 in 1921.

In 1920 the period of emergence extended over 24 days. The maximum period occurred in 1922 when moths appeared on 42 days. Emergence covered 30 days in 1918 and 34 days in 1919 and 1921.

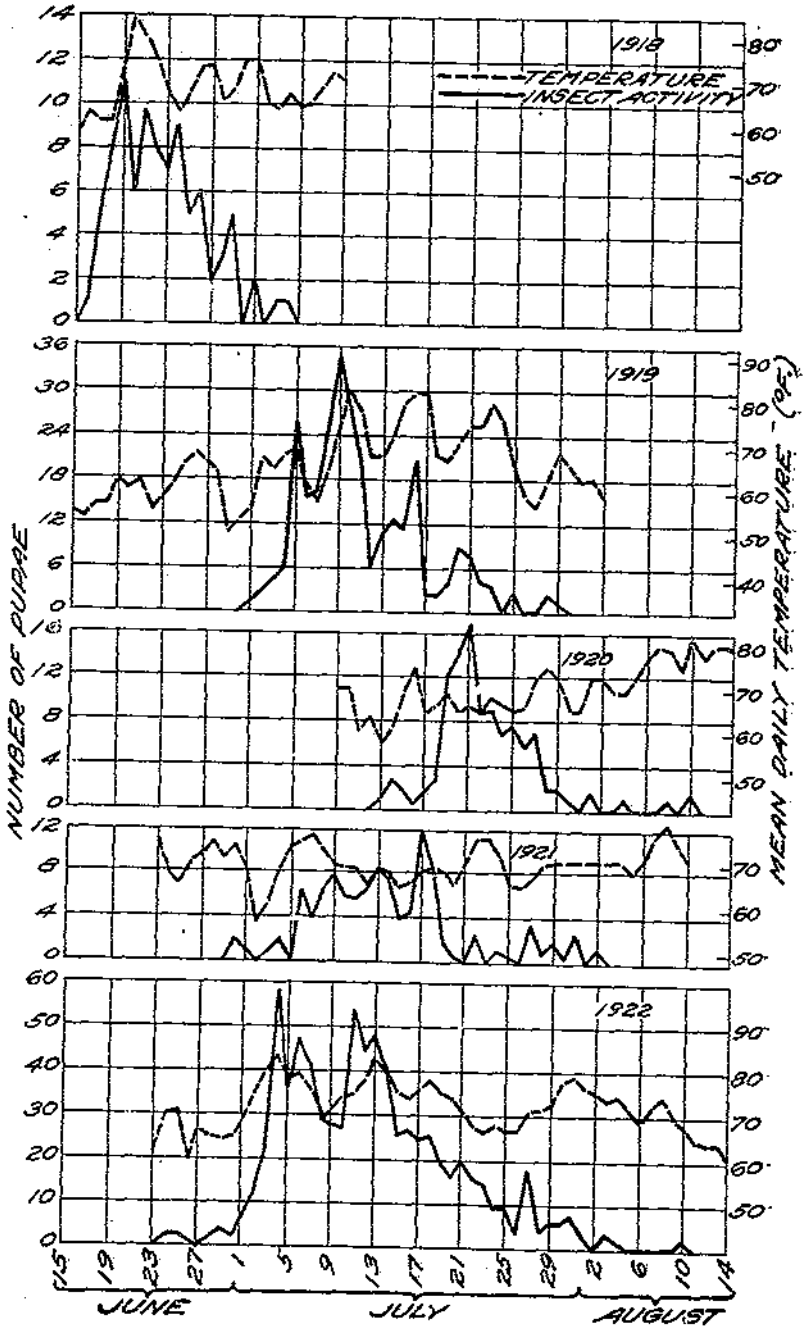

FIGURE 5.—Time of pupation of the first brood of the codling moth, Medford, Oreg.

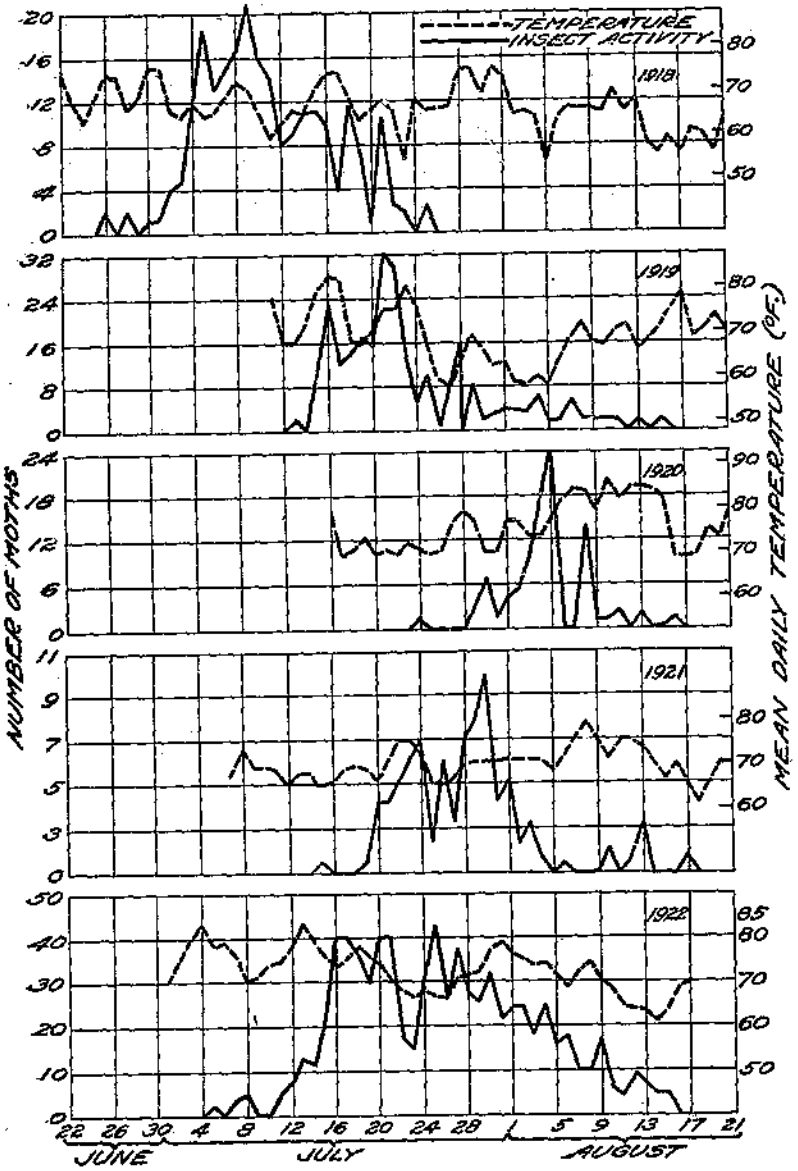

FIGURE 6.—Time of emergence of moths of the first brood of the codling moth, Medford, Oreg.

The maximum emergence occurred on widely separated days in two of the years considered. In 1918 the maximum took place on July 9, although in 1920 it did not occur until August 5. In 1919, 1921, and 1922 the dates of maximum emergence were grouped more closely in this respect, the maximum occurring on July 21, July 30, and July 25, respectively.

Oviposition by moths of the first brood.—The records in this connection are not complete for 1919. The data given below are for four years only. The oviposition records were taken on 2,435 female moths of the first brood. These moths began to lay eggs more quickly after emergence than the spring-brood moths. A large percentage of the cages showed eggs within one day after emergence. The average time before egg deposition ranged from 1.71 to 3.1 days. The maximum period before egg deposition was 12 days, and the minimum 1 day. The average time before maximum oviposition ranged from 4.29 to 7.5 days; the maximum was 24 days and the minimum 1 day. The average number of days from emergence to last oviposition varied between 9.23 days in 1921 and 17.29 days in 1922. In general the period of egg deposition was much shorter than the period for spring-brood moths.

Number of eggs per female moth.—The record for 1919 not being complete, the following averages are based on the observations of four years: The average number of eggs per female moth ranged from 23.1 to 52.4. It will be noted that the average is much higher for the first brood than for the spring brood. The maximum number of eggs deposited by one female was 241 and the minimum was 1. These records are not the results of individual observations but are taken from the records of moths in the egg-laying cages.

Length of life of moths.—The maximum length of life for the males was 42 days and for the females 35 days. The highest average length of life for female moths was 17.5 in 1920, whereas the lowest average was 9.45 days in 1921. Male moths lived an average of 15.5 days in 1920 and only 9.27 days in 1921. The minimum length of life was 1 day for both sexes.

THE SECOND GENERATION

EGGS OF THE SECOND BROOD

Time of deposition.—The daily deposition of second-brood eggs is shown graphically in Figure 7. The earliest date that eggs were deposited was July 2, 1918. Each season during the five years of observation the first eggs were deposited during July. Eggs continued to be laid until well into September and in one case until October 6. The period of egg deposition thus extended from a minimum of 63 days in 1921 to a maximum of 84 days in 1919. Certain periods occurred when eggs were being laid in maximum numbers, but generally the eggs were deposited quite regularly over a long period of time, fluctuating somewhat with the change in temperature.

Length of incubation.—The records are not complete in this connection for 1919 and 1920, but the average for the other three years varies from 7.1 days to 9.48 days. The maximum incubation period for the three years was 12 days, minimum 5 days. The period is

much shorter than for earlier broods. This is accounted for by the higher temperatures prevailing during the later periods.

LARVAE OF THE SECOND BROOD

Time of hatching.—The seasonal distribution of the hatching of larvae, or the time when fruit becomes infested, follows the distribution of oviposition with quite dependable regularity.

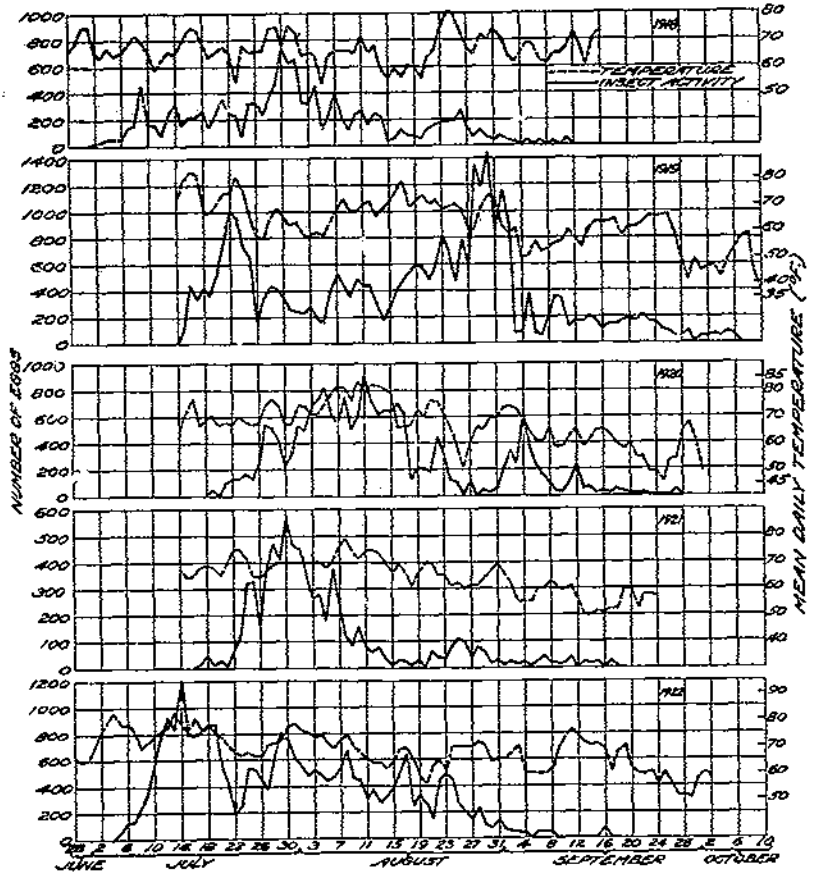

FIGURE 7.—Time of deposition of eggs of the second brood of the codling moth, Medford, Oreg.

Figure 8 presents graphically the daily hatching of eggs of the second brood for five years. The second-brood eggs generally began to hatch during the latter half of July, and hatching continued into September, or for a period of about two months. The earliest date of hatching was on July 12 in 1918 and 1922.

The first hatching usually follows oviposition at an interval of from seven to nine days. The bulk of hatching in all years was in the latter part of July and early August.

Length of the feeding period.—During the observation on the length of the feeding period of 4,173 larvae of the second brood the

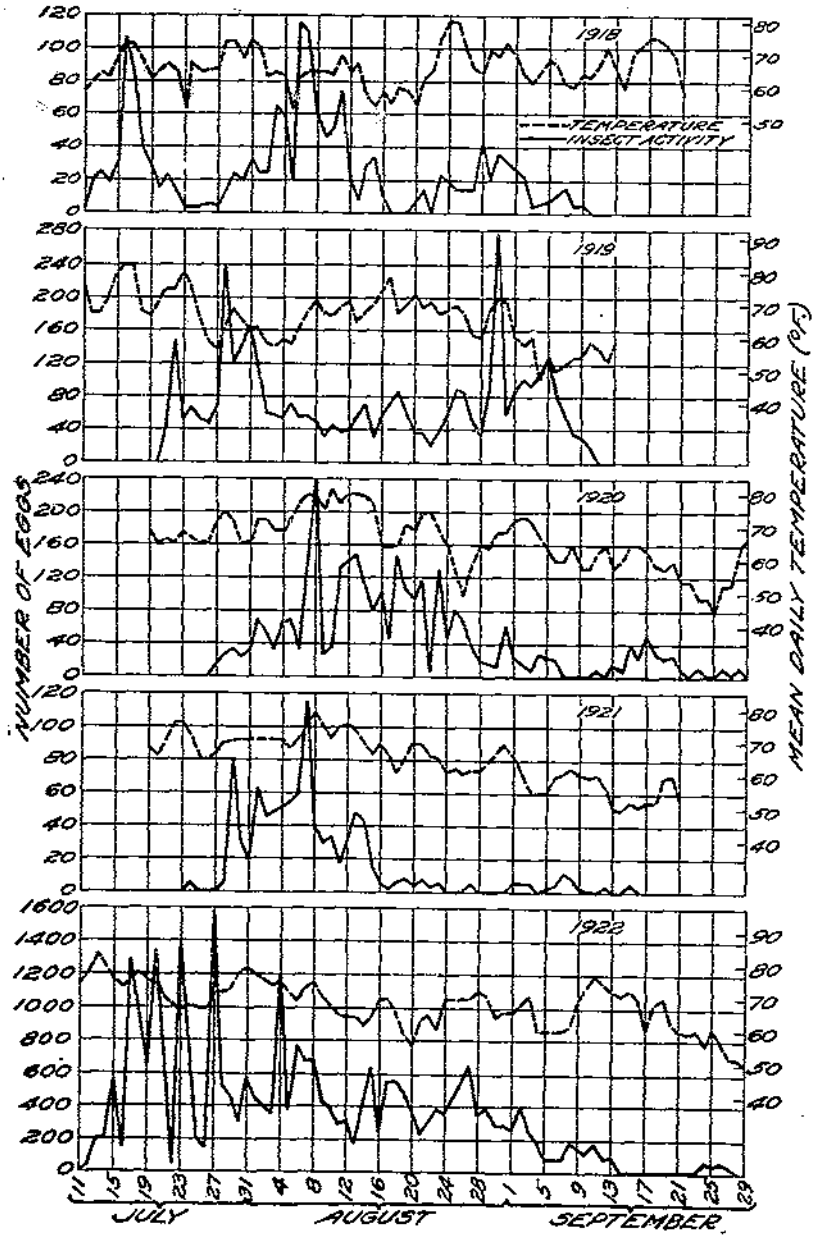

FIGURE 8.—Time of hatching of eggs of the second brood of the codling moth, Medford, Oreg.

average length of the feeding period was found to vary from 24.79 days to 30.17 days. The number of individuals observed each season was as follows: 1918, 1,079; 1919, 517; 1920, 528; 1921, 219; and 1922, 1,830. The maximum feeding period ranged from 40 days in

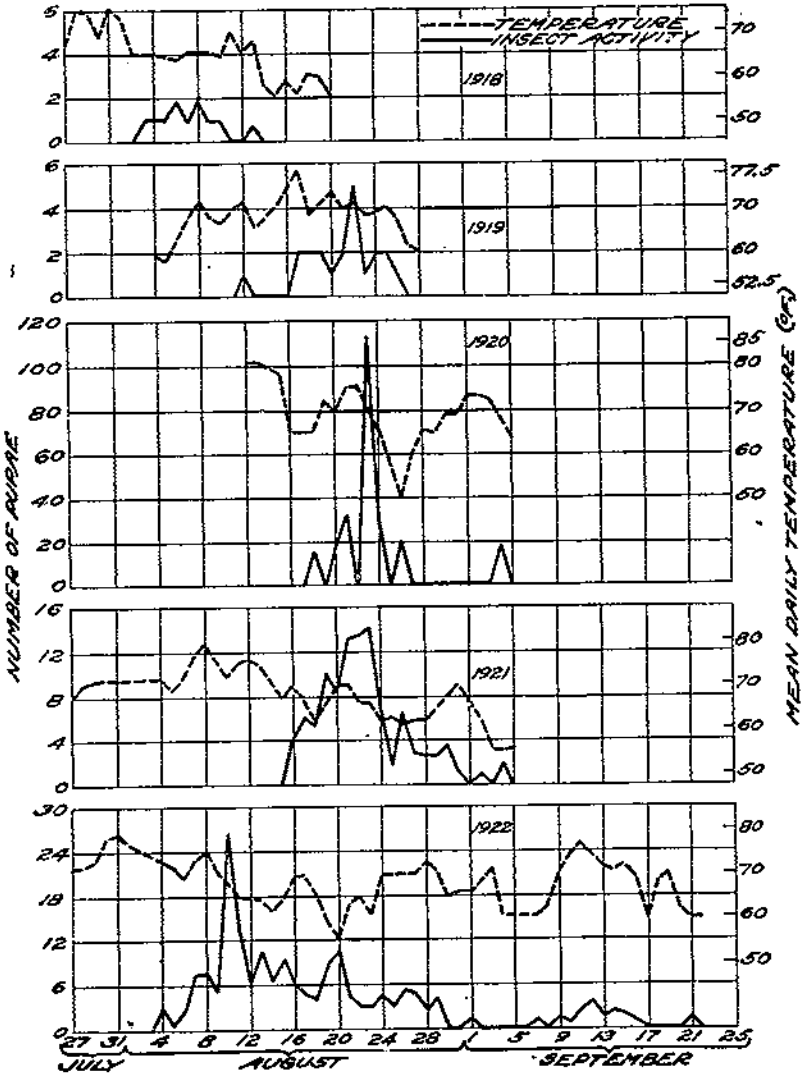

FIGURE 9.—Time of pupation of the second brood of the codling moth, Medford, Oreg.

1919 to 78 days in 1922; the minimum ranged from 9 days in 1920 to 19 days in 1921.

PUPAE OF THE SECOND BROOD

Time of pupation.—Figure 9 graphically illustrates the time of pupation of second-brood larvae over the 5-year period. The earliest pupation of larvae of this brood was noted on August 3 of 1918,

August 4 of 1922, and on August 12, 18, and 16 of 1919, 1920, and 1921, respectively.

The last pupation of 1918 was noted on August 13, the earliest of any of the five years considered. August 26 marked the cessation in 1919. Although a few larvae pupated on September 4, August 26 may be taken as practically the final date for 1920. Pupation of this brood continued until September 4 in 1921 and until September 21 in 1922.

The period in which larvae pupated varied considerably over the five years, the minimum being 11 days in 1918 and the maximum 49 days in 1922. In 1919 this period was 15 days, in 1920, 18 days, and in 1921, 20 days.

Maximum pupation took place on August 6 and 8 in 1918 and on August 23 in 1920 and 1921. Although the period of pupation in 1922 covered 49 days, the maximum was noted on August 10, or 6 days after the first larvae pupated.

Length of the pupal stage.—Records for the length of the pupal stage are not complete for 1920 and 1921. The records taken daily during 1918, 1919, and 1922 showed that the average length of this stage varied from 14.3 days to 17.47 days. The maximum number of days spent in the pupal stage was 38 in 1922, 25 in 1919, and 17 in 1918, whereas the minimum for these same years was 6, 10, and 12 days, respectively.

MOTHS OF THE SECOND BROOD

Time of emergence.—The solid lines of Figure 10 illustrate the emergence of second-brood moths from 1918 to 1922, inclusive. Average daily temperatures for the corresponding periods are indicated by the broken lines. Moths of this brood appeared earliest in 1918, the first being recorded on August 17. In three of the other years considered the first moths appeared on August 24, while in 1922 the first moth appeared on August 20. Over the 5-year period the dates for the first emergence of this brood fall within an 8-day period.

In 1918 the last moth emerged on August 28, which was considerably earlier than in the succeeding four years. The last moth appeared on September 11 in 1921 and on September 15 in 1919. In 1920 the final record was made on September 22, but the emergence was practically finished, with the exception of three individuals, by September 10. In 1922 the last moth emerged October 22.

The minimum period required for the emergence, 12 days, was in 1918, and the maximum period of 65 days occurred in 1922.

Maximum emergence is found on August 22 in 1918, which is followed closely by August 24 of 1922 and August 25 of 1920. The emergence in 1919 shows several equal peaks, but as the maximum was only two moths in each case it becomes difficult to determine the peak for this season. The latest peak occurred on September 7, 1921.

Oviposition by moths of the second brood.—Owing to the small number of moths of the second generation that were reared in the insectary, data on oviposition by this brood are somewhat meager. The records are incomplete in this connection for 1921 and 1922. The average number of days from the time of emergence to day of

first oviposition was 4.75, 5.33, 3.81, and 17.47, for 1918, 1919, 1920, and 1922, respectively. The maximum number of days from date of emergence to first oviposition was 38 and the minimum was 1. The average number of days from day of emergence to date of maximum oviposition ranged from 5.5 to 9.25, the maximum was 15, and the minimum 2. The average number of days from emer-

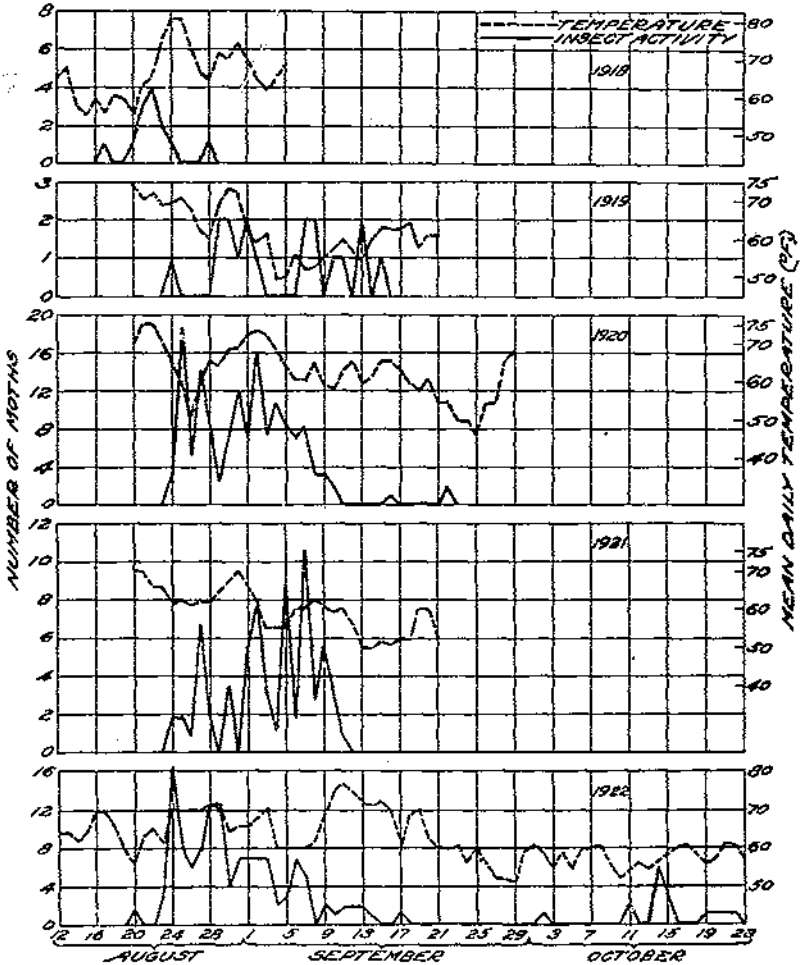

FIGURE 10.—Time of emergence of moths of the second brood of the codling moth, Medford, Oreg.

gence to last oviposition ranged from 13.5 to 21, the maximum was 23, and the minimum 11.

Number of eggs per female moth.—The average number of eggs deposited per female moth varied from 28.3 to 49.58. The maximum number of eggs deposited was 97, and the minimum 1. The records on this item were not complete for 1921.

Length of life of moths.—The length of life of male and female moths was not determined for this brood because the moths emerg-

ing on different days were placed together in egg-laying jars. More importance was placed on securing fertile third-brood eggs than on determining the length of life of moths.

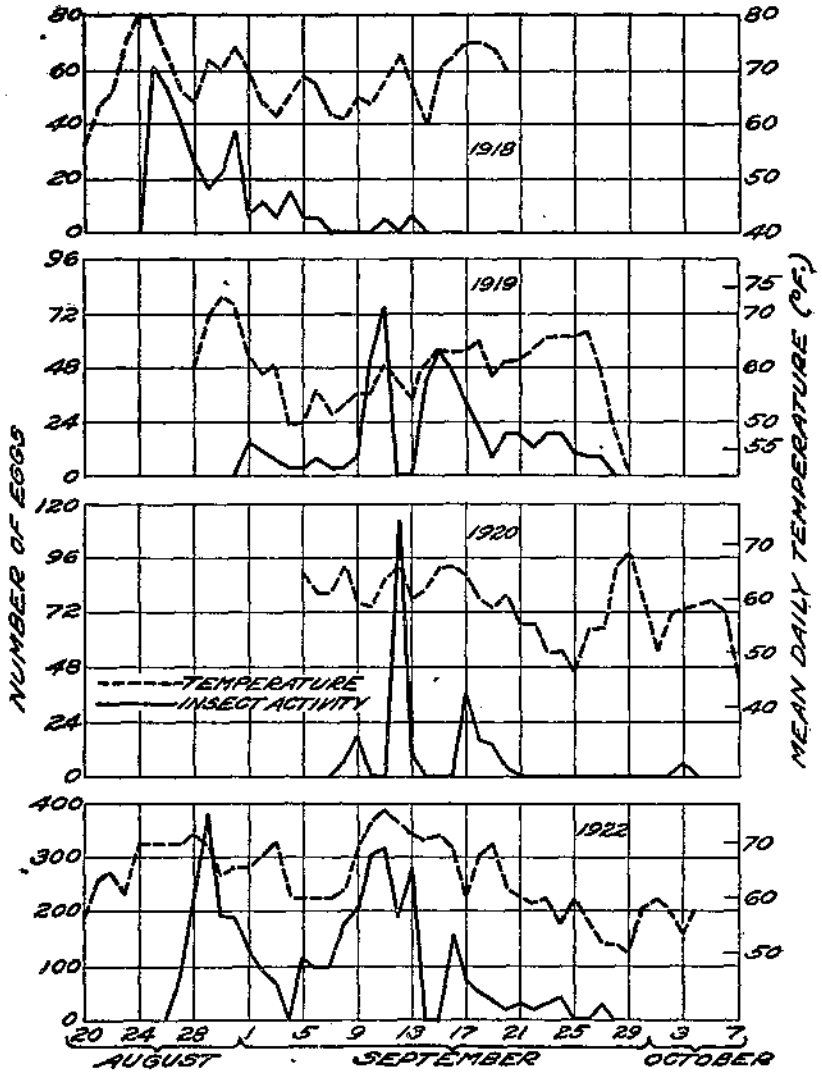

FIGURE 11.—Time of deposition of eggs of the third brood of the codling moth, Medford, Oreg.

THE THIRD GENERATION

EGGS OF THE THIRD BROOD

Time of egg deposition.—The daily records of deposition of third-brood eggs are shown in Figure 11. During the four years, deposition began during a 15-day period centered on September 1. The earliest deposition occurred on August 25, 1918, the latest on Octo-

ber 3, 1920. The period of deposition is important from the standpoint of control. The maximum deposition varies in length and time of appearance with the different seasons. During the four years the peak of deposition occurred as follows: August 25, 1918; September 11, 1919; September 12, 1920; and August 29, 1922. Deposition took place over a period varying from 20 days in 1918 to 32 days in 1922.

Length of incubation.—The incubation period of the third brood was determined for 1918, 1919, and 1922. The average length of the incubation period during the three years was 7.41, 9.04, and 10.4 days, respectively. The maximum length of the incubation period was 14 days; the minimum was 6.

LARVAE OF THE THIRD BROOD

Time of hatching.—Records of daily hatching of eggs of the third brood for three years are shown in Figure 12. Very few eggs were observed in determining the time of hatching, therefore the data are somewhat meager. The first egg of this brood hatched on August 31, 1918, six days after the first eggs were deposited. In 1919 the first eggs hatched on September 20, and in 1922 the first eggs hatched on September 4. The period of hatching during each of the three years studied was much shorter than for the earlier broods.

LARVAE OF THE THIRD BROOD

Length of the feeding period.—Individuals of this generation pass through only two stages of development, egg and larval. Inasmuch as all the third-brood larvae became overwintering larvae, along with nontransforming larvae of the first and second broods, the length of the feeding period of this brood completes the data on the normal development of the codling moth. Only two years' records on this last stage are complete. The average length of the feeding period was 28.25 days in 1918 and 44.58 days in 1922. The maximum length of the feeding period was 41 days in 1918 and 86 days in 1922, the minimum was 21 days in 1918 and 34 days in 1922.

CODLING-MOTH BAND STUDIES

BAND RECORDS FOR 1918

Band records were made in 1918 in the Wortman orchard in which the season's spraying experiments were conducted. This orchard was so situated that it represented about the average condition for the valley. Bands were placed on 70 fairly large 20 to 25 year old apple trees which were sprayed five times during the season. The spraying was not efficient enough to control the worms, consequently considerable numbers were captured, as shown in Figure 13. Larvae were emerging earlier than the bands indicate, since large numbers were captured on June 30 at the time of the first examination.

BAND RECORDS FOR 1919

The band records for 1919 were made in the Sheldon orchard, in which spraying experiments were being carried on. This tract of

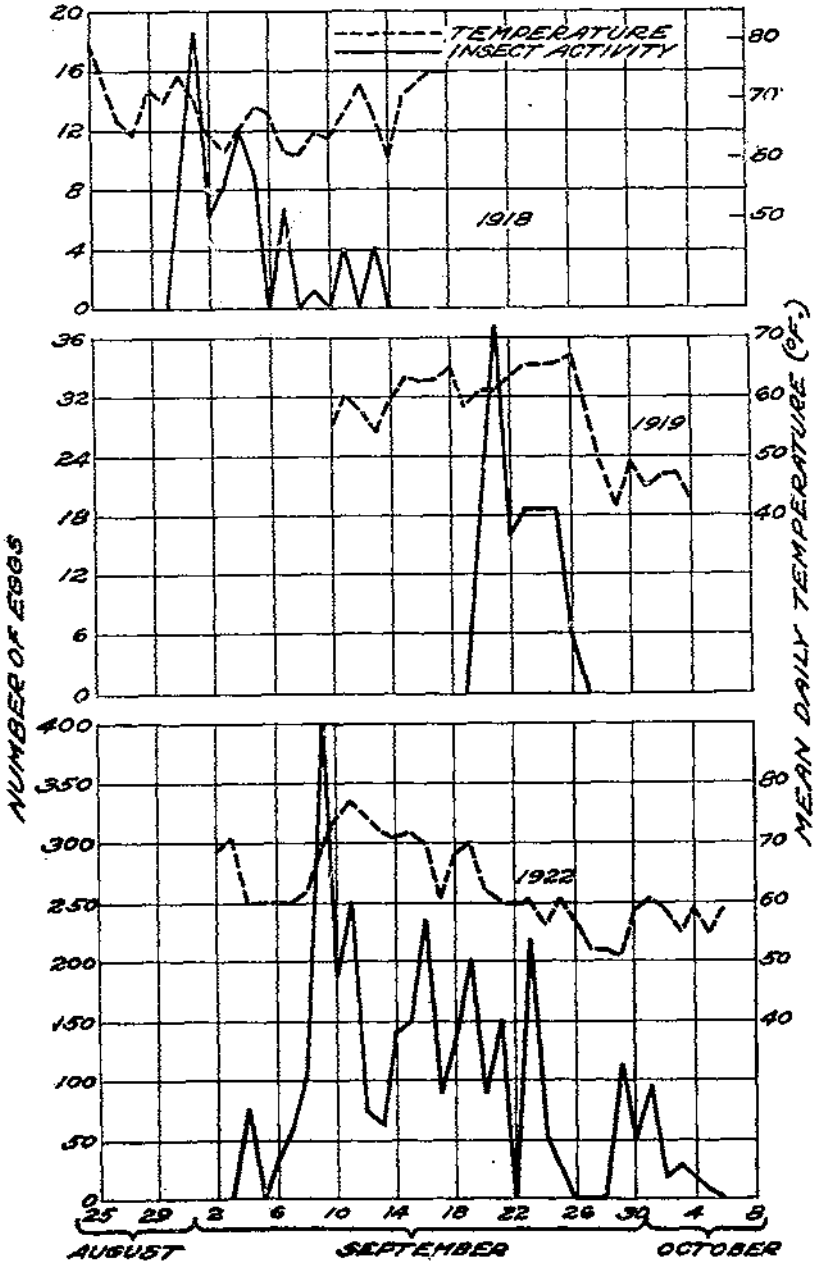

FIGURE 12.—Time of hatching of eggs of the third brood of the codling moth, Medford, Oreg.

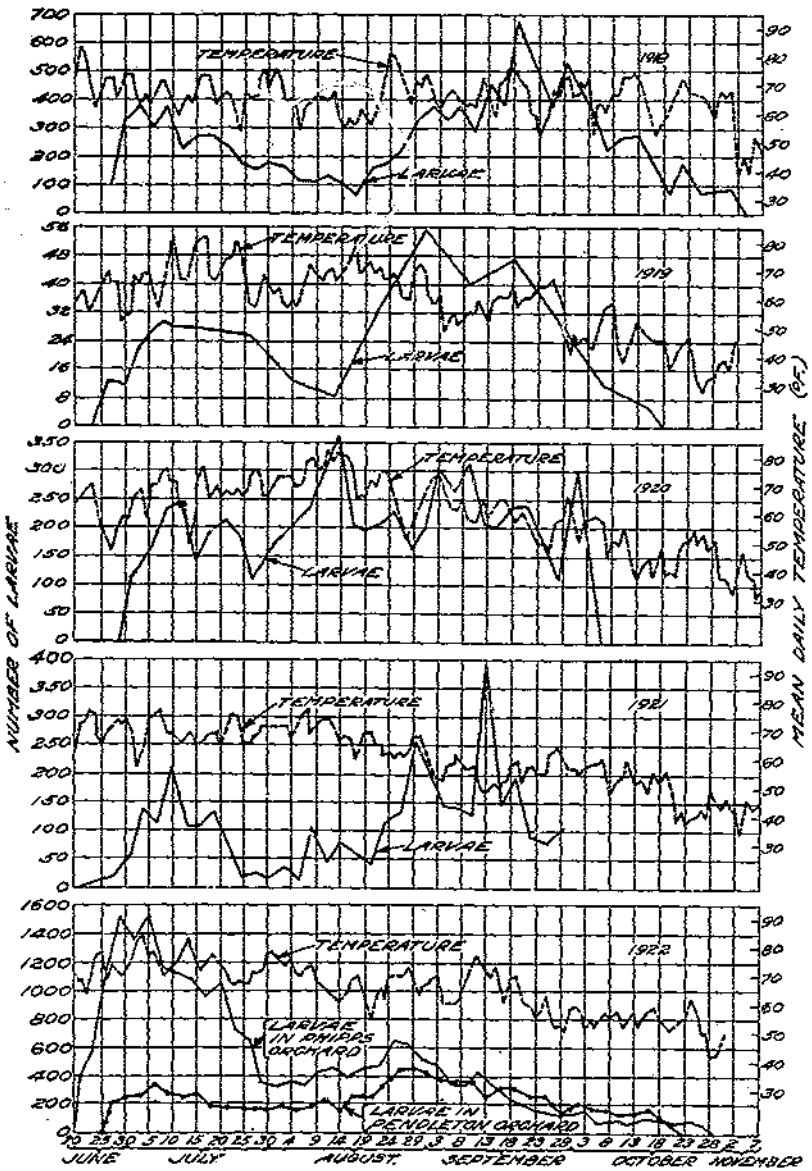

FIGURE 13.—Number of larvae of the codling moth collected from banded trees, Medford, Oreg., 1918 to 1922

15-year-old apple trees was situated on the extreme eastern edge of the fruit district and was probably freer of codling-moth infestation than many other orchards, the total infestation in most of the experimental plots running very light. For this reason comparatively few larvae were captured in the bands. A few larvae were already emerging at the time of the first examination, June 26, and a few were still entering on October 15 at the termination of the records. Although but few individuals were caught, two distinct broods were in evidence. (Fig. 13.)

BAND RECORDS FOR 1920

The band-record experiments of 1920 were conducted on 24 trees in the Phipps orchard of mixed varieties of apples 25 to 27 years old. This orchard adjoined Medford on the southeast and was fairly representative of a neglected orchard. The trees were sprayed twice in an indifferent manner; consequently considerable numbers of larvae were captured. (Fig. 13.) The bands were evidently not applied in time to catch the very earliest larvae, since large numbers were emerging on July 1, at the time of the first examination. Considerable numbers were still emerging on October 3 at the termination of the tests.

BAND RECORDS FOR 1921

The band records in 1921 were again made in the Phipps orchard, which was cared for in about the same manner as in the previous season. The October records were lost and are therefore not included in the record for this season. In this series the very earliest larvae were captured on June 24, none having been taken in the 20 bands on June 21. (Fig. 13.)

BAND RECORDS FOR 1922

The band-record experiments for 1922 were conducted in two orchards, the Phipps orchard, located on the outskirts of Medford, and the Pendleton orchard, located 12 miles north of Medford, near the northern edge of the apple and pear growing sections of the Rogue River Valley. These two widely separated orchards were chosen for the purpose of establishing better average results and to determine, as far as possible, the extent of variation in the time of development of the codling moth in the selected localities.

The trees selected in both orchards were of the Ben Davis variety, unsprayed, bearing, and in a neglected condition. The conditions were excellent for the normal growth of the insect. The trees were prepared by removing all of the rough bark scales, filling the cracks and crevices with cement, and placing 3-ply burlap bands around the trunks. The bands were examined every three days, and the larvae collected were brought to the laboratory for observation of moth emergence and for other studies.

The number of larvae taken every three days from the Phipps orchard is represented by the solid line shown in Figure 13, whereas the number of larvae collected at the Pendleton orchard is shown by the broken line. The date of collection of the first larvae and the date of maximum collection occurred earlier in the Phipps orchard, as was expected, since it was located some distance south of the

Pendleton orchard. The first larva in the Phipps orchard was collected on June 20, whereas the first larva in the Pendleton orchard was taken on June 27. The maximum number of larvae of the first brood left the apples in the Phipps orchard on June 29, while in the Pendleton orchard this occurred on July 6. Since there is an overlapping of the two broods, it is impossible, from band collections, to determine the date when the very earliest of the second brood left the fruit. According to the records, this occurred approximately during early August. In the Phipps orchard maximum numbers of second-brood larvae left the fruit on August 25 and in the Pendleton orchard on August 29. Larvae continued to leave the fruit in both orchards until late October.

It will be noted from Figure 13 that a majority of the first-brood larvae left the fruit early in the season. This was mostly due to a delayed spring and a rapid development of the season later on. The first half of April was cold and backward, and the last of April was warm, the prevailing temperature being a little above normal. The monthly report of the Weather Bureau [4] for April, 1922, states: "April was cold, cloudy, and unfavorable and was the fifth successive month with temperature below normal, and the mean temperature for Oregon was the lowest in April since the beginning of the state-wide records." For May, 1922, the report states: "This was the first month since November, 1921, to have temperature above normal."

PARASITES

In 1922 the junior writer reared three female tachinid parasites from codling-moth material collected from beneath burlap bands placed about the trunks of apple trees. The parasites were very scarce and somewhat localized in two or three orchards near Medford. They were referred to J M. Aldrich of the United States National Museum, who has identified them as *Anachaetopsis tortricis* Coq.

SUMMARY

The life-history studies recorded herein were made in the Rogue River Valley during the seasons of 1918 to 1922, inclusive.

According to the data obtained in these studies, there are two complete generations and a partial third generation of the codling moth in the Rogue River Valley.

The time of appearance and the periods of occurrence of the different stages of the codling moth for 1918, 1919, 1920, 1921, and 1922 are shown graphically in Figures 1 to 13, inclusive. The curves shown in these figures represent approximately the beginning, height, and end of activity of the more important stages of the insect, together with the approximate rate of development during the period covered.

A summarized account of the beginning, maximum, and end of the more important biological stages for 1918 to 1922, inclusive, is given in Table 3 for the purpose of a comparison of the seasonal history of these years. A summary of the life history in graphic form is presented in Figures 14, 15, 16, 17, and 18.

[4] Op. cit., see footnote 2, p. 3.

TABLE 8.—*Summary of the more important dates in the life history of the codling moth, Medford, Oreg., 1918–1922*

Period	Year	Date of—		
		Beginning	Maximum	Ending
Spring brood:				
Pupation of larvae	1918	Mar. 29	Apr. 20	May 20
	1919			May 29
	1920	Mar. 16	May 8	June 17
	1921			June 4
	1922	Apr. 4	Apr. 21	June 3
Emergence of moths	1918	Apr. 29	May 7	June 6
	1919	Apr. 18	May 14	June 24
	1920	May 15	June 4	June 27
	1921	May 9	May 25	June 10
	1922	Apr. 26	May 23	June 25
First generation:				
Deposition of eggs	1918	May 1	May 12	June 18
	1919	May 2	May 21	June 24
	1920	May 28	June 17	July 6
	1921	May 14	June 2	June 29
	1922	May 5	May 29	Do.
Hatching of eggs	1918	May 11	May 31	June 16
	1919	May 19	May 28	July 4
	1920	June 14	June 26	July 8
	1921	May 31	June 10	June 29
	1922	May 22	June 8	July 6
Larvae leaving fruit	1918	June 12	July 9	July 27
	1919	June 19	July 8	July 25
	1920	June 28	July 12	Aug. 3
	1921	June 24	July 9	Aug. 9
	1922	June 20	July 5	Do.
Pupation of larvae	1918	June 16	June 19	July 4
	1919	July 1	July 9	July 29
	1920	July 13	July 21	Aug. 10
	1921	June 30	July 17	Aug. 2
	1922	June 24	July 4	Aug. 10
Emergence of moths	1918	June 26	July 9	July 25
	1919	July 13	July 21	Aug. 15
	1920	July 24	Aug. 5	Aug. 10
	1921	July 15	July 30	Aug. 17
	1922	July 5	July 25	Aug. 15
Second generation:				
Deposition of eggs	1918	July 2	July 30	Sept. 11
	1919	July 15	Aug. 20	Oct. 6
	1920	July 19	Aug. 11	Sept. 27
	1921	July 17	July 30	Sept. 17
	1922	July 5	July 14	Sept. 16
Hatching of eggs	1918	July 12	Aug. 6	Sept. 9
	1919	July 21	Aug. 30	Sept. 10
	1920	July 27	Aug. 8	Sept. 28
	1921	July 24	Aug. 7	Sept. 15
	1922	July 12	July 27	Sept. 27
Larvae leaving fruit	1918	July 31	Sept. 19	Nov. 3
	1919	Aug. 12	Aug. 30	Oct. 18
	1920	Aug. 16	Sept. 9	Oct. 8
	1921	Aug. 12	Sept. 13	Sept. 30
	1922	July 30	Aug. 28	Nov. 28
Pupation of larvae	1918	Aug. 3	Aug. 6, 8	Aug. 13
	1919	Aug. 12	Aug. 22	Aug. 26
	1920	Aug. 18	Aug. 23	Sept. 4
	1921	Aug. 16	...do...	Do.
	1922	Aug. 4	Aug. 10	Sept. 21
Emergence of moths	1918	Aug. 17	Aug. 22	Aug. 28
	1919	Aug. 24	.....	Sept. 15
	1920	...do...	Aug. 28	Sept. 22
	1921	...do...	Sept. 7	Sept. 11
	1922	Aug. 20	Aug. 24	Oct. 22
Third generation:				
Deposition of eggs	1918	Aug. 25	Aug. 25	Sept. 13
	1919	Sept. 1	Sept. 11	Sept. 27
	1920	Sept. 8	Sept. 12	Oct. 3
	1922	Aug. 27	Aug. 29	Sept. 27
Hatching of eggs	1918	Aug. 31	Sept. 1	Sept. 13
	1919	Sept. 20	Sept. 21	Sept. 26
	1922	Sept. 4	Sept. 9	Oct. 5
Larvae leaving fruit	1918	Sept. 22	Sept. 29	Oct. 18
	1922	Oct. 7	Oct. 26	Dec. 5

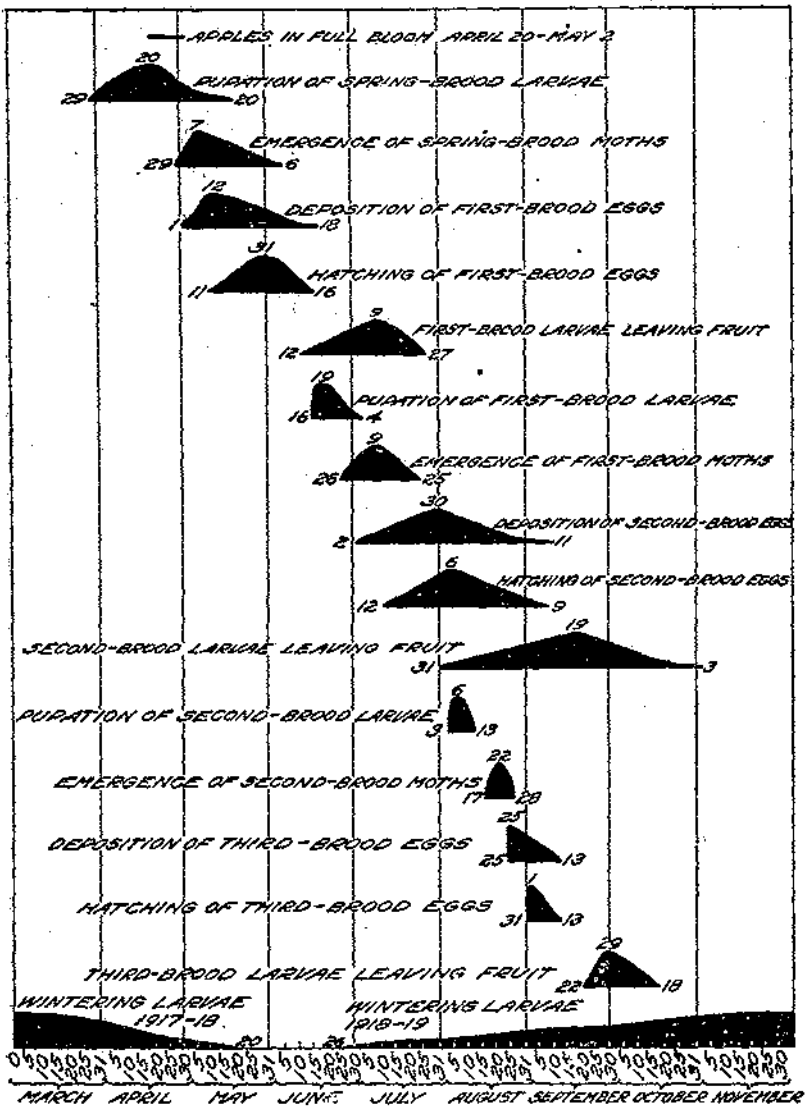

FIGURE 14.—Diagram of the life history of the codling moth at Medford, Oreg., 1918

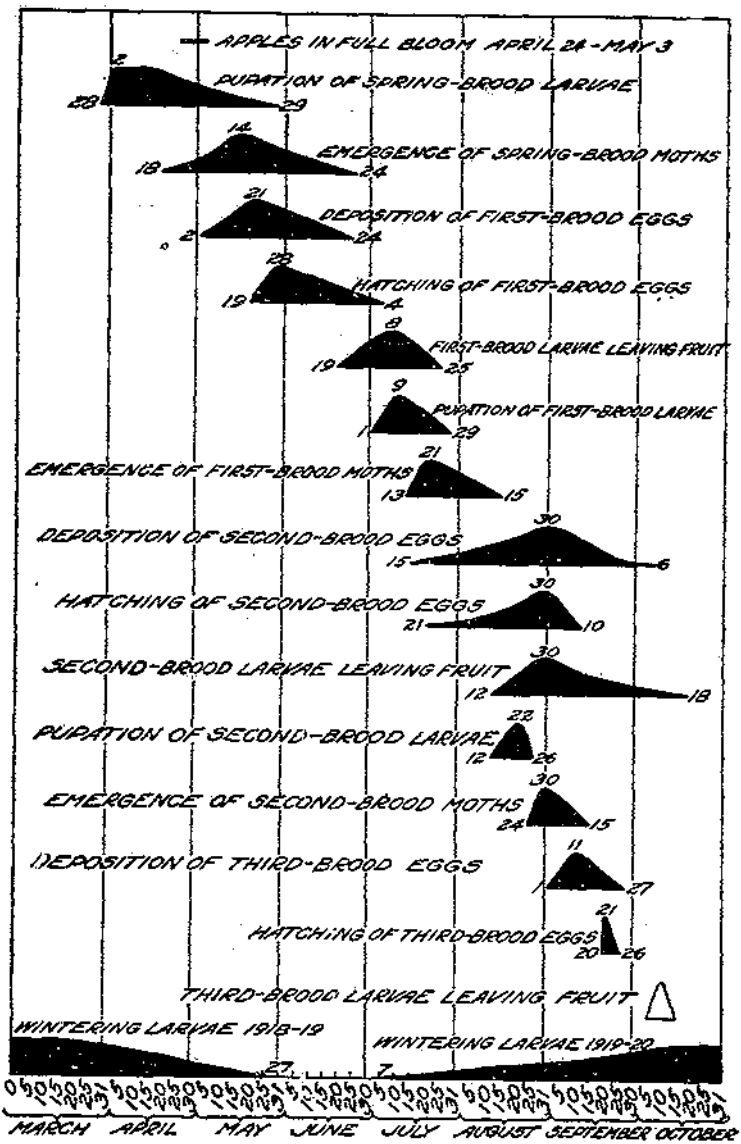

FIGURE 15.—Diagram of the life history of the codling moth at Medford, Oreg., 1919

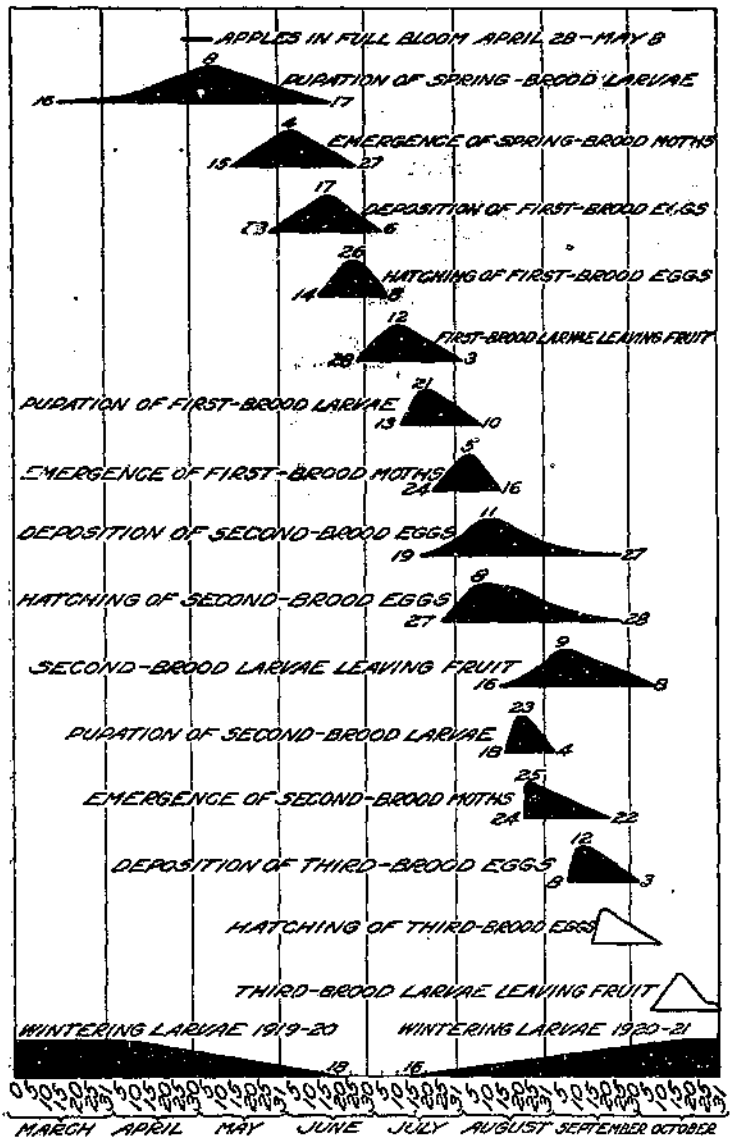

FIGURE 16.—Diagram of the life history of the codling moth at Medford, Oreg., 1920

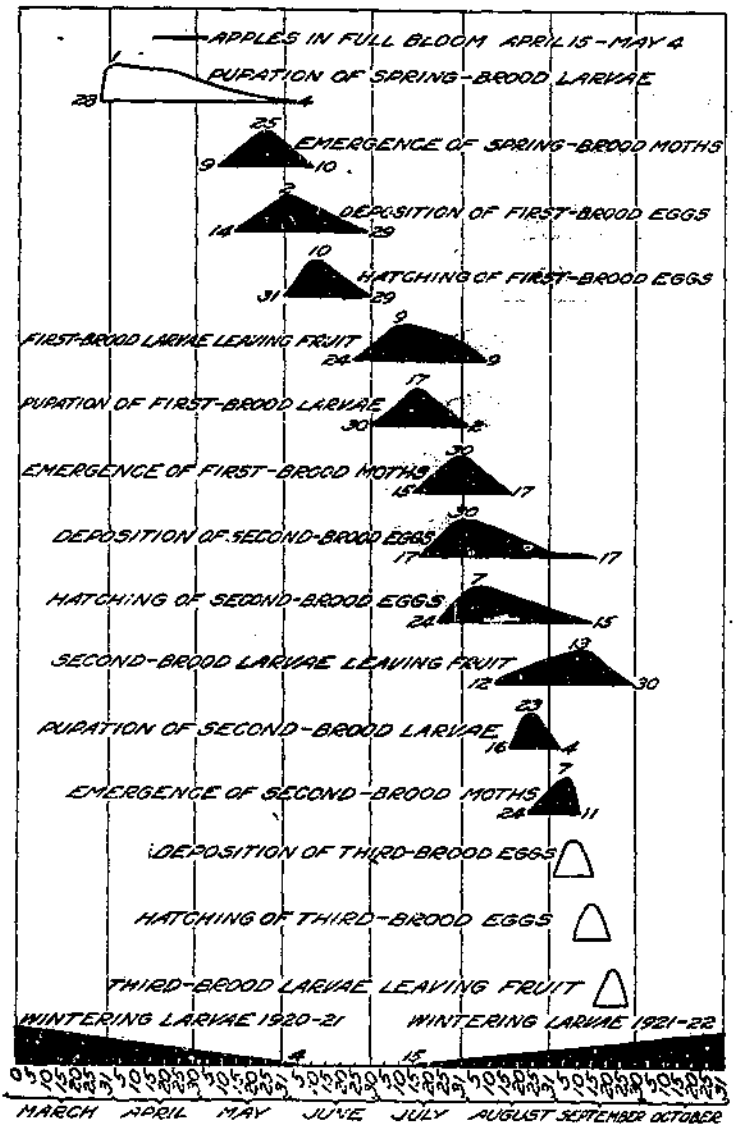

FIGURE 17.—Diagram of the life history of the codling moth at Medford, Oreg., 1921

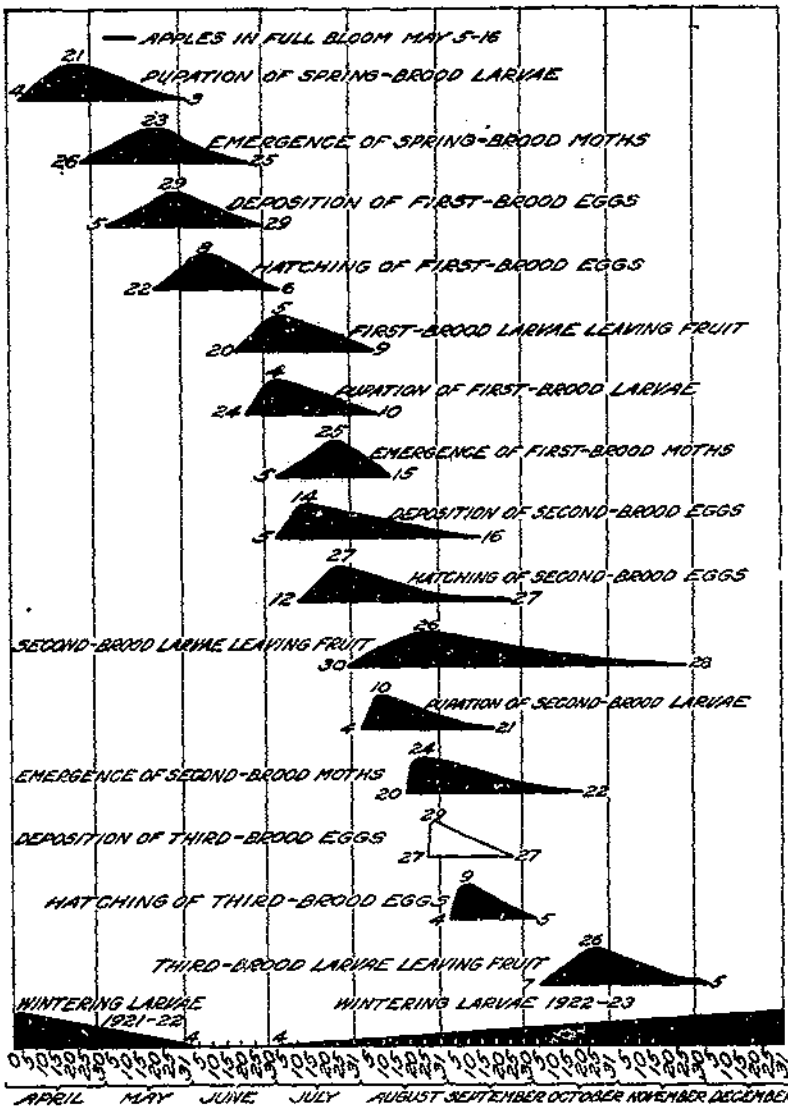

FIGURE 18.—Diagram of the life history of the codling moth at Medford, Oreg., 1922

A summarized review of data on the development of the various stages of the codling moth, with the average number of eggs per female moth, is given in Table 4 for the years 1918 to 1922, inclusive, for the purpose of comparing the minimum, average, and maximum length of each stage under observation for the years named. All figures are in terms of days, except in the case of the items giving the average number of eggs per female moth, which naturally are in terms of eggs.

TABLE 4.—*Summary of data on the development of the more important stages of the codling moth, Medford, Oreg., 1918–1922*

Stage of development	Year	Number	Minimum [1]	Average [1]	Maximum
Spring brood:					
Length of pupal stage	1918	340	19	28.04	35
	1919	623	24	36.42	45
	1920	418	14	31.80	60
	1921	302	25	43.80	56
	1922	412	16	25.56	53
Length of preoviposition period	1918	328	1	6.49	14
	1919	355	2	5.97	16
	1920	369	1	5.21	14
	1921	270	1	4.20	16
	1922	375	1	3.12	9
Period before maximum oviposition	1918	328	3	9.34	24
	1919	355	3	10.90	21
	1920	369	2	8.70	15
	1921	270	1	8.10	26
	1922	375	1	7.45	16
Period from emergence to last oviposition	1918	328	3	16.80	37
	1919	355	7	20.20	27
	1920	369	5	15.03	24
	1921	270	3	12.81	19
	1922	375	2	17.91	32
Number of eggs per female moth	1918	328	1	10.68	26
	1919	355	1	10.23	44
	1920	369	1	6.15	26
	1921	270	1	10.69	89
	1922	376	1	29.07	85
Length of life of male moths	1918	319	1	14.9	38
	1919	345	2	15.24	38
	1920	297	1	15.04	31
	1921	285	2	13.5	25
	1922	360	2	13.18	38
Length of life of female moths	1918	300	1	14.4	37
	1919	310	3	16.6	36
	1920	327	2	14.08	27
	1921	230	2	15.5	29
	1922	353	2	16.61	35
First generation:					
Length of incubation period	1918	626	5	14.31	22
	1919	611			
	1920	212			
	1922	10,066	7	10.62	17
Length of larval feeding period	1918	245	15	20.07	33
	1919	289	16	28.27	42
	1920	154	27	30.6	52
	1922	886	18	22.43	41
Length of cocooning period	1918	220	3	4.32	18
	1919	250	2	6.81	20
	1920	126	4	4.42	23
	1922	782	2	5.93	29
Length of pupal stage	1918	85	11	13.6	21
	1919	460	6	12.13	28
	1920	96	8	14.95	17
	1921	86	10	14.3	24
	1922	719	7	13.02	31
Period before oviposition	1918	387	2	3.10	7
	1919		1	2.45	6
	1920	651	1	2.5	11
	1921	337	1	2.7	12
	1922	670	1	1.71	3
Period before maximum oviposition	1918	387	2	7.5	23
	1919		2	6.36	20
	1920	651	1	5.61	24
	1921	337	1	4.52	12
	1922	670	2	4.29	10

[1] All figures represent days, except those for the number of eggs per moth.

TABLE 4.—*Summary of data on the development of the more important stages of the codling moth, Medford, Oreg., 1918–1922.*—Continued

Stage of development	Year	Number	Minimum[1]	Average[1]	Maximum[1]
First generation—Continued.					
Period from emergence to last oviposition	1918	387	9	16.58	27
	1919		8	15.54	31
	1920	651	10	13.24	24
	1921	337	2	9.23	23
	1922	670	9	17.29	28
Number of eggs per female moth	1918	387	2	34.10	181
	1919	598	2	52.4	241
	1920	651	2	32.4	90
	1921	337	1	23.1	58
	1922	670	4	40.51	112
Length of life of male moths	1918	256	2	11.7	25
	1919	525	2	12.34	34
	1920	487	2	15.6	29
	1921	314	1	9.27	23
	1922	635	2	13.34	42
Length of life of female moths	1918	325	1	12.6	30
	1919	598	2	12.99	33
	1920	637	2	17.5	33
	1921	305	2	9.45	20
	1922	670	1	14.16	35
Second generation:					
Length of incubation period	1918	1,564	5	7.1	11
	1921	906	5	7.43	12
	1922	26,570	7	9.48	12
Length of larval feeding period	1918	1,079	10	24.81	49
	1919	517	15	24.79	40
	1920	528	9	25.4	46
	1921	210	19	27.31	45
	1922	1,830	16	30.17	78
Length of cocooning period	1918	13	3	6.19	28
	1919	376	3	9.35	31
	1922	139	2	8.18	22
Length of pupal stage	1918	13	12	15.61	17
	1919	315	10	14.3	25
	1922	146	6	17.47	39
Period before oviposition	1918	8	3	4.75	6
	1919	18	3	5.33	8
	1920	91	1	3.81	11
	1922	77	8	17.47	38
Period before maximum oviposition	1918	8	4	9.25	13
	1919	18	2	5.5	8
	1920	91	2	8.36	15
	1922	77			
Period from emergence to last oviposition	1918	8	12	13.5	15
	1919	18	20	21.0	23
	1920	91	11	14.45	20
	1922	77		15.6	
Number of eggs per female moth	1918	8	7	36.12	81
	1919	18	10	28.3	97
	1920	91	1	30.04	56
	1922	77		49.58	
Length of life of male moths	1919	492	2	11.9	30
	1922	63			
Length of life of female moths	1919	589	2	12.9	33
	1922	77			
Third generation:					
Length of incubation period	1918	70	6	7.41	9
	1919	128	8	9.04	10
	1922	2,862	7	10.4	14
Length of larval feeding period	1918	27	21	28.25	41
	1922	62	34	44.58	86

[1] All figures represent days, except those for the number of eggs per moth.

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