U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN NO. 80.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

I. THE CODLING MOTH IN THE OZARKS.
By E. L. JENNE, *Engaged in Deciduous Fruit Insect Investigations.*

II. THE CIGAR CASE-BEARER.
By A. G. HAMMAR, *Engaged in Deciduous Fruit Insect Investigations.*

III. ADDITIONAL OBSERVATIONS ON THE LESSER APPLE WORM.
By S. W. FOSTER AND P. R. JONES, *Engaged in Deciduous Fruit Insect Investigations.*

IV. THE PEAR THRIPS AND ITS CONTROL.
By DUDLEY MOULTON, *Engaged in Deciduous Fruit Insect Investigations.*

V. ON THE NUT-FEEDING HABITS OF THE CODLING MOTH.
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VI. LIFE HISTORY OF THE CODLING MOTH IN NORTHWESTERN PENNSYLVANIA.
By A. G. HAMMAR, *Engaged in Deciduous Fruit Insect Investigations.*

VII (REVISED). THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.
By A. L. QUAINTANCE, *In Charge of Deciduous Fruit Insect Investigations,*
AND
E. L. JENNE, E. W. SCOTT, AND R. W. BRAUCHER,
Engaged in Deciduous Fruit Insect Investigations.

VIII. TESTS OF SPRAYS AGAINST THE EUROPEAN FRUIT LECANIUM AND THE EUROPEAN PEAR SCALE.
By P. R. JONES, *Engaged in Deciduous Fruit Insect Investigations.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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Deciduous Fruit Insect Investigations.

A. L. Quaintance, *in charge.*

Fred Johnson, E. L. Jenne, P. R. Jones, A. G. Hammar, R. A. Cushman, J.B. Gill, R. L. Nougaret, W. M. Davidson, L. L. Scott, F. E. Brooks, W. B. Wood, E. B. Blakeslee, E. H. Siegler, A. C. Baker, *agents and experts.*
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S. W. Foster, W. H. Sill, *employed in enforcement of insecticide act, 1910.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., November 20, 1911.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 80, eight papers dealing with deciduous fruit insects and insecticides. These papers, which were issued separately during the years 1909–10, are as follows: The Codling Moth in the Ozarks, by E. L. Jenne; The Cigar Case-Bearer, by A. G. Hammar; Additional Observations on the Lesser Apple Worm, by S. W. Foster and P. R. Jones; The Pear Thrips and Its Control, by Dudley Moulton; On the Nut-Feeding Habits of the Codling Moth, by S. W. Foster; Life History of the Codling Moth in Northwestern Pennsylvania, by A. G. Hammar; The One-Spray Method in the Control of the Codling Moth and the Plum Curculio, by A. L. Quaintance, E. L. Jenne, E. W. Scott, and R. W. Braucher; Tests of Sprays Against the European Fruit Lecanium and the European Pear Scale, by P. R. Jones.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The present series of articles on deciduous fruit insects and insecticides, Parts I to VIII, comprises Bulletin 80.

The first article, on the codling moth in the Ozarks, is a report on two years' study of the life history of this insect, which is very destructive in that locality. For the first time three generations of larvæ have definitely been established.

The cigar case-bearer, treated in the second paper, is an insect that periodically attracts attention by reason of its injuries. During the outbreak of this species in the general region of North East, Pa., during the season of 1908, exceptional opportunity was presented for a study of its life history and habits, as detailed in the paper in question.

The lesser apple worm was the subject of an article issued in 1908 as Part V of Bulletin 68. At that time the egg had not been found, and there was question whether this species fed to any extent upon the twigs of apple. Further observations on this important apple insect are presented in Part III, in which the egg stage is described, although previously noted by Mr. E. P. Taylor, and it was also found that the boring of apple twigs is due to the work of another species.

The fourth paper, on the pear thrips and its control, comprises the second report upon this species, which is so destructive to deciduous fruits in the San Francisco Bay region in California. The first paper, issued as Part I of Bulletin 68, contained the principal facts in the life history of the insect, which are repeated and extended in the present paper, with the addition of many data resulting from large-scale experiments with remedies in orchards. Practicable control measures are indicated.

The feeding of the codling moth upon nuts has been occasionally recorded in the literature of this insect, although the evidence has been inconclusive, and it was the consensus of opinion among entomologists that the insect never normally fed upon nuts. Part V of the present bulletin details definite extended observations showing that under certain conditions in California the codling moth is a serious pest in its work on English or Persian walnuts.

Part VI, which deals with the life history of the codling moth in northwestern Pennsylvania, follows in general the plan of treatment of Part I of this bulletin, and constitutes the second article dealing with the detailed life history of this insect in an important fruit region. Similar studies are under way or planned covering the principal fruit sections of the United States. A report will shortly be prepared dealing with the codling moth in Michigan.

During the past few years there has been considerable interest aroused, following the experience of certain western entomologists and orchardists, in the practicability of controlling the codling moth by a single thorough application immediately after the falling of the petals. This so-called one-spray method has been compared with the usual spraying schedule in vogue in the East by numerous eastern entomologists, and the results of the investigations of this bureau on the relative merits of these two spraying methods in the control of the codling moth and also in the control of the plum curculio are detailed in Part VII.

The final paper, Part VIII, reports on tests of sprays against the European fruit Lecanium and the European pear scale, two serious scale-insect enemies of deciduous fruits in California.

A. L. Quaintance,

In Charge of Deciduous Fruit Insect Investigations.

CONTENTS.[1]

[1] The eight papers constituting this bulletin were issued in separate form on June 26 and 30, Aug. 12, and Sept. 1, 1909, and Sept. 20 and Nov. 28, 1910 (three papers on the last date). Part VII, revised, was issued on Mar. 30, 1911.

ILLUSTRATIONS

PLATES.

TEXT FIGURES.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CODLING MOTH IN THE OZARKS.

By E. L. Jenne,
Engaged in Deciduous Fruit Insect Investigations.

In 1907 the Bureau of Entomology undertook some experimental and demonstration spraying for the control of the codling moth at Siloam Springs, Benton County, Arkansas. The work being largely investigation of remedies, only a few notes relating to the life history of the insect were secured. The following season a fuller line of rearing work was conducted at the same place, and the present account of the codling moth in that locality applies mainly to the season of 1908. Data for 1907 are introduced for comparison, where it is possible.

In 1908 the rearing work was conducted out of doors. Moths were confined in Riley rearing cages; larvæ were reared in fruit inclosed in paper bags on the trees, or in picked fruit in muslin-covered battery jars; and the pupal periods were observed in small vials.

SEASONAL HISTORY.

SPRING BROOD OF PUPÆ.[a]

Duration of the brood.—The earliest pupæ did not come under observation, but judging from the first emergence of moths and the length of the earliest observed spring pupal stages, pupation began in late February or early March.

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[a] The term "brood" is used in speaking of any single stage of the insect, and "generation" to include all the stages of the life cycle.

The pupæ and moths produced by the transformation of the wintering larvæ are sometimes termed "first-brood pupæ" and "first-brood moths." Here, however, the first generation is regarded as beginning with the first eggs of the season, and ending with the moths that develop therefrom. Where three generations of the insect occur, the adult stages are spoken of as moths of spring brood, moths of first brood, and moths of second brood. The adults of the third generation become the spring brood of moths for the succeeding year. The spring moths lay the first-brood eggs, the first-brood moths lay the second-brood eggs, and second-brood moths lay the third-brood eggs.

On March 24 there were taken, from rubbish on the ground under an outdoor apple bin at a vinegar factory, 6 pupæ and 130 larvæ. They were located in a damp place, shaded during the greater part of the day. Above, in crevices of the apple bin, were many cocoons, for the most part inaccessible, but those that could be examined showed a much larger proportion of pupæ.

On March 31 some timbers were pried from this bin and larvæ and pupæ were found in about equal numbers—122 larvæ and 112 pupæ. This bin was situated on the west side of the building and was built of 2 by 4 material, nailed, 1 inch apart, to large supporting timbers. The cocoons occurred between the scantlings and their supports. This should represent fairly normal conditions above ground. Even here pupæ would be found greatly in the majority under one scantling, while beneath an adjoining one nearly all cocoons might contain larvæ. This was evidently due to the fact that some of the pine scantlings were sapwood, which absorbs much moisture during rains. At the time of examination they were damp and soggy, though no rain had fallen for several days. Under these the proportion of pupæ was much smaller than under dry scantlings adjoining.

No empty pupal cases were found March 31, although one adult moth, evidently just emerged, was captured while sunning itself on the bin. On April 21 the bin was again examined, and there were found 79 larvæ, 114 pupæ, and 64 empty cases. This showed that about 70 per cent of the wintering larvæ had pupated up to that time. But even yet larvæ were in the majority in damp and shaded parts.

Nearly all of the larvæ collected on the above dates and kept out of doors in vials had pupated by May 12. Two belated individuals pupated May 19 and 20. This gives a probable time of 2½ months during which wintering larvæ transformed to pupæ. Apple trees bloomed about the middle of this period. The majority of the spring pupæ had given out adults by May 27, the two belated individuals emerging June 6 and 8. Thus there is a period of about 3 months during which spring pupæ were present—from the first of March until June.

Length of spring pupal stage.—Individual records were obtained of 131 spring pupæ, from larvæ collected at the out door apple bin. The material was kept out of doors in vials in a pasteboard box, under as nearly a normal temperature as possible. The length of the pupal stage steadily decreased with the advancement of the season. Doubtless a longer period would have been shown for the first pupæ of the season if they could have been observed.

The records of the spring pupal stages are given in Tables I and II, with a summary in Table III.

TABLE I.—*Length of pupal periods in spring brood of pupæ—from wintering larvæ collected March 31.*

Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.	Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.
			Days.				*Days.*
1	Apr. 1	May 1	30	43	Apr. 14	May 11	27
2	Apr. 2	Apr. 28	26	44	..do	..do	27
3	..do	Apr. 30	28	45	..do	..do	27
4	..do	May 3	31	46	Apr. 15	..do	26
5	Apr. 4	May 1	27	47	..do	..do	26
6	Apr. 5	May 2	27	48	..do	..do	26
7	Apr. 6	May 3	27	49	..do	..do	26
8	..do	May 4	28	50	..do	..do	26
9	Apr. 7	..do	27	51	..do	..do	26
10	Apr. 8	..do	26	52	..do	May 12	27
11	..do	May 5	27	53	Apr. 16	May 11	25
12	..do	..do	27	54	..do	..do	25
13	Apr. 9	..do	26	55	..do	..do	25
14	Apr. 10	..do	25	56	..do	May 12	26
15	..do	..do	25	57	..do	..do	26
16	..do	..do	25	58	..do	..do	26
17	Apr. 11	..do	24	59	..do	..do	26
18	..do	..do	24	60	..do	..do	26
19	..do	..do	24	61	Apr. 17	May 11	24
20	..do	May 8	27	62	..do	May 12	25
21	..do	..do	27	63	..do	May 13	26
22	..do	May 9	28	64	..do	..do	26
23	..do	May 10	29	65	..do	..do	26
24	Apr. 12	May 9	27	66	..do	May 14	27
25	..do	May 10	28	67	Apr. 18	May 12	24
26	..do	..do	28	68	..do	..do	24
27	Apr. 13	May 9	26	69	..do	May 13	25
28	..do	..do	26	70	..do	May 14	26
29	..do	May 10	27	71	..do	..do	26
30	..do	..do	27	72	..do	May 15	27
31	..do	..do	27	73	Apr. 19	..do	26
32	..do	..do	27	74	..do	..do	26
33	..do	..do	27	75	..do	May 16	27
34	..do	..do	27	76	Apr. 20	May 15	25
35	..do	..do	27	77	..do	May 16	26
36	Apr. 14	..do	26	78	..do	..do	26
37	..do	..do	26	79	Apr. 21	May 15	24
38	..do	..do	26	80	..do	May 16	25
39	..do	..do	26	81	Apr. 22	..do	24
40	..do	..do	26	82	..do	..do	24
41	..do	May 11	27	83	Apr. 23	May 17	24
42	..do	..do	27				

TABLE II.—*Length of pupal periods in spring brood of pupæ—from wintering larvæ collected April 21.*

Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.	Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.
			Days.				*Days.*
1	Apr. 22	May 16	24	25	May 3	May 25	22
2	..do	May 17	25	26	May 4	May 22	18
3	Apr. 23	May 19	26	27	..do	..do	18
4	Apr. 24	May 18	24	28	May 5	..do	17
5	Apr. 25	..do	23	29	..do	..do	17
6	..do	..do	23	30	..do	..do	17
7	..do	..do	23	31	..do	..do	17
8	..do	..do	23	32	..do	..do	17
9	Apr. 26	May 19	23	33	..do	..do	17
10	..do	..do	23	34	..do	..do	17
11	Apr. 27	..do	22	35	..do	May 23	18
12	Apr. 28	..do	21	36	..do	..do	18
13	Apr. 30	May 20	20	37	May 6	May 22	16
14	May 1	..do	19	38	..do	May 23	17
15	..do	..do	19	39	May 8	..do	15
16	..do	..do	19	40	..do	..do	15
17	..do	May 21	20	41	..do	..do	15
18	May 3	May 20	17	42	May 10	..do	13
19	..do	May 21	18	43	May 11	May 25	14
20	..do	..do	18	44	May 12	..do	13
21	..do	..do	18	45	..do	May 27	15
22	..do	..do	18	46	May 13	May 26	13
23	..do	..do	18	47	May 19	June 8	20
24	..do	May 22	19	48	May 20	June 6	17

TABLE III.—*Spring brood of pupæ—summary of pupal periods shown in Tables I and II.*

Wintering larvæ collected.	Number of individuals.	Maximum pupal life.	Minimum pupal life.	Average pupal life.
		Days.	*Days.*	*Days.*
March 31	83	31	24	26.2
April 21	48	26	13	18.5
Both lots	131	31	13	23.5

SPRING BROOD OF MOTHS.

Duration of emergence.—Emergence began out of doors March 31, on which date we captured a moth while collecting wintering material at the outdoor apple bin. As no empty pupal cases were found this may be considered the beginning of emergence. Ben Davis apple trees were in full bloom at this time. From wintering material collected March 31, moths began emerging April 9. Some probably would have issued earlier had not a large proportion of the pupæ been injured in collecting. On again examining the apple bin, on April 21, the numerous empty pupal cases indicated that about 25 per cent of the moths had issued, there being found 64 empty cases and 193 larvæ and pupæ. By May 27 all moths had emerged from collected wintering material except two belated individuals which issued June 6 and 8. The latter date coincides with the issuance of the first moth of the first brood. Briefly, the spring brood of moths issued during a period of 2 months, beginning with the date of full-bloom of apple trees (March 31).

The emergence of moths from collected wintering material is shown in Table IV.

TABLE IV.—*Emergence of spring brood of moths—summary of emergence records from wintering material collected March 24, March 31, and April 21.*

Date.	Number of moths emerging.	Date.	Number of moths emerging.	Date.	Number of moths emerging.	Date.	Number of moths emerging.	Date.	Number of moths emerging.
Apr. 9	1	Apr. 20	1	May 1	3	May 12	16	May 23	8
Apr. 10	2	Apr. 21	3	May 2	9	May 13	12	May 24	1
Apr. 11	0	Apr. 22	4	May 3	10	May 14	0	May 25	3
Apr. 12	0	Apr. 23	11	May 4	13	May 15	11	May 26	2
Apr. 13	1	Apr. 24	2	May 5	22	May 16	11	May 27	1
Apr. 14	0	Apr 25	4	May 6	2	May 17	8	June 6	1
Apr. 15	2	Apr. 26	0	May 7	0	May 18	7	June 8	1
Apr. 16	1	Apr. 27	0	May 8	3	May 19	5		
Apr. 17	2	Apr. 28	1	May 9	0	May 20	10		
Apr. 18	4	Apr. 29	2	May 10	27	May 21	6		
Apr. 19	1	Apr. 30	1	May 11	29	May 22	11		

The data given in Table IV are shown graphically in the accompanying curve, figure 1.

The above record is from 320 larvæ and 232 pupæ collected March 24, March 31, and April 21 from the outdoor apple bin. These 552 larvæ and pupæ produced 275 adults. A much larger number of pupæ than of larvæ were injured in collecting and failed to give out moths. This, together with the fact that 193 of the total number collected were taken after emergence had begun, would throw the maximum of emergence here shown considerably later than it should be. As before stated, about 25 per cent of the moths had emerged in the field, from cocoons above ground, by April 21.

In 1907 Mr. Dudley Moulton records the finding of a few empty pupal skins while collecting wintering material in an open packing shed April 27. This was 25 days after the apple blossoms had fallen, a period of cold weather occupying the interval. From material then collected moths continued to issue in the laboratory until June 1.

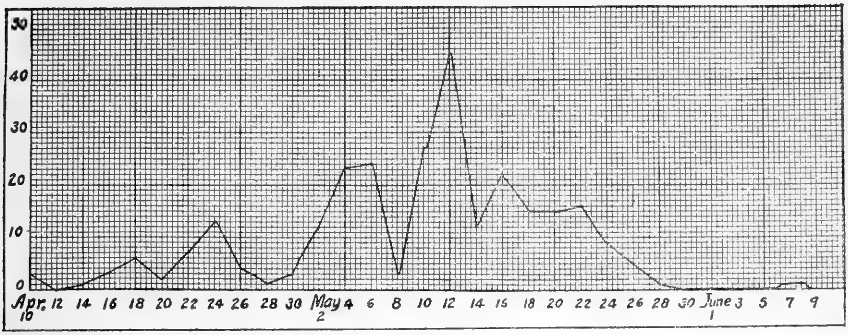

FIG. 1.—Curve showing emergence of spring brood of adults of codling moth (*Carpocapsa pomonella*) from collected wintering material.

Life of the moth.—Records of 28 spring-brood moths emerging April 13–23, and confined in a Riley rearing cage out of doors, show an average life of 10.5 days. Another lot of 35 moths that emerged April 25 to May 4 gives an average life of 9.1 days. The life of the moths is largely dependent on temperature. They are able to lay fertile eggs in 3 to 5 days after emergence, but during cold weather in spring or fall they remain torpid for long periods. Moths can be fed by putting into the cage a piece of raw cotton soaked in sirup or fruit juice. However, even without food, if a sufficient number of moths are confined together, eggs will be laid abundantly. Data on caged spring-brood moths are given in Tables V and VI. These moths issued from the wintering material collected March 24 and March 31.

TABLE V.—*Life of spring brood of moths—Cage I.*

Moths emerged and put into cage.		Moths died.		Average life of moths.	Eggs laid (at night).	
Date.	Number.	Date.	Number.		Date.	Number.
April 13	1	April 19	1		April 19	23
April 15	2	April 20	1		April 24	46
April 16	1	April 22	1		May 2	16
April 17	2	April 24	4			
April 18	4	April 28	2			
April 19	1	April 29	3			
April 20	1	April 30	5	10.5 days.		
April 21	3	May 1	1			
April 23	15	May 2	1			
		May 3	2			
Total	30	May 4	3			
		May 5	1			
		May 9	2			
		May 10	1			
		Escaped	2			

TABLE VI.—*Life of spring brood of moths—Cage II.*

Moths emerged and put into cage.		Moths died.		Average life of moths.	Eggs laid (at night).	
Date.	Number.	Date.	Number.		Date.	Number.
April 25	4	May 2	2		May 4	5
April 28	1	May 4	1		May 8	16
April 29	2	May 5	1		May 11	45
May 1	2	May 6	3			
May 2	9	May 7	1			
May 3	12	May 9	2			
May 4	10	May 10	5	9.1 days.		
		May 11	4			
Total	40	May 12	3			
		May 13	2			
		May 14	4			
		May 15	3			
		May 16	2			
		May 17	2			
		Escaped	5			

THE FIRST GENERATION.

FIRST-BROOD EGGS.

Period of oviposition.—Eggs were not laid in the rearing cages as early as in the field, because of the lack of a sufficient number of the earliest moths. Eggs collected in the field began to hatch April 27, which, from the earliest observed periods of incubation, would indicate that oviposition had commenced as early as April 7. Apple blossoms had nearly all fallen by April 7. Eggs were abundant in the orchard on April 27, 67 eggs being collected from the lower branches of 2 trees in the space of half an hour. Of these, 6 were empty shells, 2 showed the black head of the larva and hatched the same day, 36 showed the red ring, and 23 were undeveloped. Eggs continued abundant in the orchard during the early part of May.

The last unhatched eggs of the first brood were found May 27. Empty shells were numerous in the orchard at that time, but only 3 unhatched eggs were found, all of them in the "black-spot" stage. This date seems to be near the end of the first brood of eggs, and agrees with the issuing records of moths from collected wintering material, practically all moths having emerged by this time.

In 1907 the last of the first-brood eggs were obtained June 2, having been laid in a cage by the last moths to emerge from collected wintering material kept in the laboratory.

Place of oviposition.—Of 67 eggs collected in the orchard April 27, 53 occurred on the upper side of leaves, 13 on the back of leaves, and 1 on a twig. While bagging fruit on May 6 a careful examination for eggs was made on all the leaves, twigs, and fruit to be inclosed in the bags. There were 78 eggs or empty shells found, of which 76 were on the upper surface of leaves, 1 on a twig, and 1 on the side of the fruit. Since but few apples became wormy after being bagged, this represents nearly the whole number of eggs present on the parts examined. Some of the eggs were at a considerable distance from any fruit, but as a rule the moths seemed to have selected the fruit clusters, possibly only because the foliage there was denser than on isolated shoots.

In the cages eggs were placed indiscriminately on all parts of twigs, leaves, fruit, framework of cage, and on the glass panes, always, however, on the side of the cage from which most light came. Twigs placed in the middle or on the darker side of the cage were disregarded, the moths depositing their eggs on the side or bottom of the cage while struggling to fly out toward the light.

Fertility.—Practically all eggs observed were fertile, whether laid in cages or collected in the orchard. Often a few sterile eggs were deposited in the cages before oviposition proper began. When eggs were laid in considerable numbers they were all fertile.

Length of incubation period.—The egg stage was greatly lengthened by periods of cool weather such as are apt to occur in early spring. The first eggs obtained in cages were deposited the night of April 19. These were subjected to very cool weather, including frost, and gave a maximum period of 21 days, or an average of 19.6 days. Eggs deposited the night of April 24 experienced part of the same spell of cool weather, including frost, and required an average of 17 days to hatch. With the advent of warm weather the egg stage was rapidly shortened. Eggs deposited May 8 hatched in 8½ days, and the lot laid May 10 hatched in 7½ days. Undoubtedly the last eggs of the first brood would show the uniform period of 5 days required for second-brood and third-brood eggs laid during June, July, and August. In Table VII are shown the incubation records of first-brood eggs deposited in outdoor cages.

TABLE VII.—*First-brood eggs—incubation records of eggs laid in Cages I and II (recorded in Tables V and VI).*

A. 21 EGGS LAID IN CAGE I.

Number of eggs.	When laid (night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
2	Apr. 19	Apr. 27	May 4	May 6	17
5	...do.....	...do.....	May 5	May 8	19
11	...do.....	...do.....	...do.....	May 9	20
3	...do.....	...do.....	...do.....	May 10	21

B. 46 EGGS LAID IN CAGE I.

Number of eggs.	When laid (night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
1	Apr. 24	May 2	May 10	May 11	16
2	...do.....	...do.....	May 9	May 12	17
6	...do.....	...do.....	May 10	...do.....	17
30	...do.....	...do.....	May 11	...do.....	17
4	...do.....	May 3	...do.....	...do.....	17
1	...do.....	May 2	...do.....	May 13	18
1	...do.....	May 3	....	May 14	19

C. 16 EGGS LAID IN CAGE II.

Number of eggs.	When laid (night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
16	May 8	....	....	May 17 a. m.	8.5

D. 45 EGGS LAID IN CAGE II.

Number of eggs.	When laid (night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
45	May 10	....	....	May 17 p. m. May 18 a. m.	7.5

FIRST-BROOD LARVÆ.

Period of hatching.—The date of the earliest hatching of larvæ can be put fairly accurately at about April 27 (3 weeks after petals had fallen), as on that day out of 67 eggs collected in the orchard only 6 were empty shells and 2 in the black-spot stage, hatching the same day. No wormy apples were found until May 4, the calyx lobes probably concealing their work for several days. Larvæ continued to enter the fruit in numbers during nearly the whole of May. The last of the brood probably entered during the first week of June, which is allowing 10 days from the time of the last observed unhatched egg in the orchard. The great majority of the first brood of larvæ entered the fruit during May.

Thus it will be seen that up to this time the different stages of the insect, instead of showing an increasing tendency to occupy a longer time, have actually become more compact. While it required about 2½ months for the wintering larvæ to pupate, the spring moths issued within a space of 2 months and the first brood of larvæ hatched in scarcely more than 45 days. This is readily explainable from the influence of temperature on the different stages. The earliest spring pupal stages lasted a month, but the later individuals to transform spent only 2 weeks as pupæ; so that the time of emergence of the spring moths was shortened by 15 days. Again, the first eggs required 20 days to hatch, and the last only 5, a shortening by another 15 days of the period during which the first brood of larvæ entered the fruit.

In 1907 the first larva was found in the orchard May 18, newly hatched, and in the act of entering the calyx. This was 6 weeks after the petals had fallen from the apple trees. Several wormy apples were found May 23, and they soon became abundant. On June 17 to 20, observations by Mr. Dudley Moulton at Bentonville, Ark., and by the writer at Siloam Springs indicated that the first brood had nearly all entered. Over 500 wormy apples were collected in orchards at the two places, but no larvæ just entering were found, the smallest larvæ having burrowed to the core.

Maturing of larvæ.—In 1908 the first cocoon was found under a band May 27, and contained a newly transformed pupa (soft and white), indicating that the larva had left the fruit not later than May 24. Two full-grown larvæ left picked fruit May 26, the fruit having been collected in the orchard that day. The band record from 18 trees (page 24) indicates that the last of the first brood of larvæ went into cocoons about July 15, or 52 days after the first larva left the fruit. This gives an increase of about a week over the time between the first and last entering larvæ of this brood.

In 1907 the first mature larvæ left picked fruit June 12. On June 17 many larvæ and some pupæ were taken from bands, the last previous examination of the bands being on June 10. In 1906 larvæ had begun to spin cocoons by June 5, as indicated by a sending of wormy fruit from Bentonville, Ark., by Mr. W. M. Scott to Mr. Moulton. Several larvæ had spun up en route.

Period in fruit.—Several of the earlier larvæ of the first brood hatched and were placed on bagged fruit May 4. Six larvæ reached maturity, leaving the fruit May 26–29, after an average life in the apple of 23.8 days, the minimum being 22 and the maximum 25 days. A greater range would probably occur in the field between larvæ in exposed fruit and those in the shaded interior of the trees.

Larval life in cocoon.—Forty-three larvæ which became full grown before July 10 showed an average interval of 7.2 days between leaving the fruit and pupation when kept in vials out of doors. The shortest interval was 3 days and the longest 19. The normal time in the orchard is probably nearer the minimum here shown, as in the glass vials many larvæ seemed to spend an unusually long time trying to build a suitable cocoon. Individual records on this stage are given in Table VIII.

FIRST-BROOD PUPÆ.

First-brood larvæ began to pupate May 27, just a week after the last stragglers of the wintering larvæ under observation had pupated. Thus first-brood pupæ appeared before the last of the spring brood had given out moths, the extent of the overlap being 12 days.

Of 42 first-brood pupæ observed, the average duration of the stage was 10.7 days, ranging from 9 to 13 days. The total period from the time the larva left the fruit until the adult issued averaged 17.8 days, with a range of from 13 to 21 days. As before suggested, larvæ not confined in vials would probably pupate sooner, thus shortening the "cocoon stage." Individual records of first-brood pupæ are shown in Table VIII.

Table VIII.—*Pupal periods and cocoon stages of first generation.*

Individual No.	Larva left fruit.	Larva pupated.	Moth emerged.	Length of pupal stage.	Total time in cocoon.
				Days.	*Days.*
1	May 29	June 2	June 12	10	14
2	...do	...do	...do	10	14
3	...do	...do	...do	10	14
4	May 30	June 3	...do	9	13
5	...do	...do	June 13	10	14
6	...do	June 5	June 18	13	19
7	May 31	June 4	June 15	11	15
8	June 2	June 5	June 16	11	14
9	...do	June 6	...do	10	14
10	...do	June 7	June 18	11	16
11	June 3	June 6	June 16	10	13
12	June 4	June 9	June 21	12	17
13	June 5	June 8	June 19	11	14
14	...do	June 12	June 23	11	16
15	...do	June 21	July 3	13	28
16	June 6	June 11	June 22	11	16
17	...do	June 13	June 24	11	18
18	June 8	...do	...do	11	16
19	...do	June 16	June 26	10	18
20	June 9	...do	June 28	12	19
21	June 11	...do	June 25	9	14
22	June 15	June 19	June 30	11	15
23	June 16	June 23	July 5	12	17
24	June 21	June 24	...do	11	14
25	June 23	June 29	July 11	12	18
26	...do	July 7	July 17	10	24
27	June 24	July 2	July 12	10	18
28	...do	July 5	July 16	11	22
29	June 27	July 7	July 17	10	20
30	June 28	July 3	July 13	10	15
31	June 30	July 7	July 17	10	17
32	July 1	July 5	...do	12	16
33	July 2	July 8	July 18	10	16
34	...do	July 11	July 20	9	18
35	...do	July 16	July 27	11	25
36	July 3	July 9	July 18	9	15
37	July 7	July 20	Aug. 1	12	25
38	...do	July 26	Aug. 7	12	31
39	July 8	July 23	Aug. 2	10	25
40	July 9	July 15	July 26	11	17
41	...do	July 18	July 29	11	20
42	...do	July 25	Aug. 4	10	26

FIRST-BROOD MOTHS.

The earliest first-brood moth emerged June 8, on which date the last belated moth of the spring brood also issued. Sixteen of the earliest moths, caged June 8–15, showed an average life of 6.2 days. Oviposition began 5 days after the first moth was caged. In 1907, when a large number of moths were caged on the same date, eggs were obtained on the third day. A record of first-brood moths confined in a cage is given in Table IX.

TABLE IX.—*Life of first-brood moths (Cage III), reared from first-brood larvæ from earliest wormy apples collected in orchard, and from earliest larvæ reared in bagged fruit.*

Moths emerged and put into cage.		Moths died.		Average life of moths.	Eggs laid (at night).	
Date.	Number.	Date.	Number.		Date.	Number.
June 8	1	June 16	1	6.2 days.	June 13	2
June 9	1	June 18	1		June 14	16
June 11	1	June 19	7		June 15	26
June 12	5	June 21	7		June 16	18
June 14	2	Escaped	5		June 17	104
June 15	11				June 18	25
Total	21	Total	16		Total	191

In 1907 no first-brood moths were obtained until June 25. In 1906 Mr. Moulton records the issuing of a moth on June 19 from apples sent from Bentonville, Ark.

LENGTH OF LIFE CYCLE OF FIRST GENERATION.

The interval between the emergence of the first adult of the wintering brood and the earliest first-brood moth was 69 days. Starting with a spring moth emerging after the weather became warm, the life cycle would be much shorter. A moth emerging May 5 might lay eggs May 10. Eggs laid on the latter date required 7½ days to hatch. This, together with 24 days in the fruit and 18 days in the cocoon, gives a total of about 54 days as an average time for the latter half of the first generation.

THE SECOND GENERATION.

SECOND-BROOD EGGS.

The earliest of the first brood of moths began depositing eggs on the night of June 13. In 1907 second-brood eggs were not laid in cages until July 5. All eggs of this brood required a nearly uniform period of 5 days for incubation. In Table X is given a record of the incubation of some of the earlier eggs of this brood.

TABLE X.—*Second-brood eggs—incubation periods of eggs laid in Cage III (recorded in Table IX).*

Number of eggs.	Eggs laid (at night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
26	June 15	June 18	June 20	June 21	5½
18	June 16	June 19	June 21	[a]do	5
104	June 17	do	June 22	[a]June 22	5
25	June 18	June 20	....	June 23	5½

[a] At night.

SECOND-BROOD LARVÆ.

Period of hatching.—According to records of oviposition, the first larvæ of the second brood would have hatched June 18. They began hatching in numbers in the cages June 21. Reared larvæ entering fruit as late as August 3 were undoubtedly of the second brood, as they pupated on reaching full growth. Some of the brood probably hatched later still, making a total period of entrance to the fruit of perhaps 55 days for such larvæ of this brood as pupated.

Maturing of larvæ.—The band record (p. 24) indicates that second-brood larvæ began to leave the fruit by July 15. The first of the reared larvæ left July 13, and were from eggs laid 4 days later than the earliest, so mature second-brood larvæ may have appeared by July 10. The band records of both 1907 (p. 23) and 1908 (p. 24) indicate that the last of the second brood left the fruit early in September.

Period in fruit.—A large number of second-brood larvæ hatching during the night of June 22 were transferred to bagged fruit June 25. Seventeen of these reached maturity after an average time in the fruit of 24.6 days, the time ranging from 21 to 31 days. The individual records are given in Table XI.

TABLE XI.—*Life of second-brood larvæ, reared in bagged fruit on trees (eggs recorded in Table X).*

Number of larvæ.	When hatched.	Date of leaving fruit.	Time in fruit.
	Night.		*Days.*
1	June 22	July 13	21
4	...do.....	July 14	22
1	...do.....	July 15	23
4	...do.....	July 16	24
1	...do.....	July 17	25
2	...do.....	July 18	26
2	...do.....	July 19	27
1	...do.....	July 20	28
1	...do.....	July 23	31

Several of the same lot of larvæ were put on picked fruit and kept in jars out of doors. Most of these spun cocoons in the fruit, and had pupated before the fact was noticed. Three of them, however, left the fruit after periods of 21 and 22 days. The fact that these larvæ had been kept in jars instead of on bagged fruit seems to have hastened development, as the average time from oviposition to emergence of adult of 11 individuals of this lot was 42.3 days, as against 49.5 days for the 17 individuals on bagged fruit. Nine second-brood larvæ hatching July 28 to August 3 were reared in picked fruit in jars, and reached maturity in from 16 to 20 days, the average being 17.7 days. Individual records of this lot are given in Table XII.

TABLE XII.—*Life of second-brood larvæ, reared in picked fruit in jars out of doors.*

Number of larvæ.	When hatched.	Date of leaving fruit.	Time in fruit.
			Days.
2	July 28	Aug. 15	18
1	...do.....	Aug. 14	17
1	July 31	Aug. 17	17
1	Aug. 2	Aug. 20	18
1	Aug. 3	Aug. 22	19
1	...do.....	Aug. 23	20
1	...do.....	Aug. 19	16
1	...do.....	...do.....	16

In 1907 the period in the fruit was determined for 33 second-brood larvæ which hatched July 10–15. All were reared in picked fruit kept in the laboratory. The shortest time was 15 days, longest 22, average 18.1 days. The 1907 rearings are tabulated in Table XIII.

TABLE XIII.—*Life of second-brood of larvæ, reared in picked fruit, in laboratory—1907*

Number of larvæ.	Date of hatching.	Date of leaving fruit.	Time in fruit.
			Days.
2	July 10	July 27	17
2	...do.....	July 29	19
1	...do.....	July 30	20
1	July 15	...do.....	15
2	...do.....	July 31	16
9	...do.....	Aug. 1	17
7	...do.....	Aug. 2	18
4	...do.....	Aug. 3	19
1	...do.....	Aug. 4	20
2	...do.....	Aug. 5	21
2	...do.....	Aug. 6	22

Larval life in cocoon.—Of 75 larvæ maturing from July 12 to September 1, the time between leaving the fruit and pupation (in vials out of doors) varied from 3 to 21 days, with an average of 11.86 days. The remarks on this stage of the first-brood larvæ would also apply here. Individual records are shown in Table XIV.

SECOND-BROOD PUPÆ.

Pupæ appeared out of doors as late as September 14. These, however, were from larvæ that left the fruit September 1 or before, and only a few larvæ leaving the fruit later than August 20 transformed. In the laboratory pupæ appeared well into November. In 1907 larvæ appearing under bands later than August 26 generally failed to pupate, so that the last pupæ in both seasons appeared early in September.

Of 78 second-brood pupæ, from larvæ maturing after July 12 and until September 1, the longest pupal stage was 17 days, shortest 8, average 10.5 days. The longest total period in cocoon was 38 days, shortest 12, average 20.4 days. This material was kept in small vials, and the period between leaving the fruit and pupation was probably abnormally long, on account of the difficulty in spinning a suitable cocoon. The individual records are given in Table XIV.

TABLE XIV.—*Pupal periods and cocoon stages of second generation.*

Individual No.	Larva left fruit.	Larva pupated.	Moth emerged.	Time as pupa.	Time in cocoon.
				Days.	*Days.*
1	July 12	July 17	July 26	9	14
2	..do.....	July 22	Aug. 2	11	21
3	July 13	July 21	July 31	10	18
4	..do.....	July 24	Aug. 2	9	20
5	July 14	July 17	July 27	10	13
6	..do.....	July 28	Aug. 6	9	23
7	..do.....	..do.....	Aug. 7	10	24
8	..do.....	July 31	Aug. 10	10	27
9	July 15	July 29	Aug. 7	9	23
10	July 16	July 25	Aug. 3	9	18
11	..do.....	..do.....	..do.....	9	18
12	..do.....	July 22	July 30	8	14
13	..do.....	July 28	Aug. 7	10	22
14	July 17	Aug. 2	Aug. 11	9	25
15	July 18	July 22	July 31	9	13
16	..do.....	July 26	Aug. 4	9	17
17	July 19	..do.....	Aug. 3	8	15
18	..do.....	..do.....	..do.....	8	15
19	..do.....	July 28	Aug. 6	9	18
20	July 20	Aug. 7	Aug. 18	11	19
21	July 21	July 28	Aug. 6	9	16
22	..do.....	July 29	Aug. 7	9	17
23	July 23	July 31	Aug. 10	10	18
24	..do.....	Aug. 4	Aug. 16	12	24
25	July 24	July 30	Aug. 8	9	15
26	..do.....	Aug. 1	Aug. 11	10	18
27	July 25	Aug. 2	..do.....	9	17
28	July 29	Aug. 11	Aug. 19	8	21
29	Aug. 1	Aug. 16	Aug. 27	11	26
30	..do.....	Aug. 11	Aug. 19	8	18
31	Aug. 2	Aug. 6	Aug. 16	10	14
32	..do.....	Aug. 11	Aug. 19	8	17
33	..do.....	Aug. 12	Aug. 22	10	20
34	Aug. 3	Aug. 11	Aug. 19	8	16
35	..do.....	Aug. 14	Aug. 25	11	22
36	..do.....	Aug. 17	Aug. 28	11	25
37	Aug. 4	Aug. 11	Aug. 22	11	18
38	..do.....	Aug. 12	Aug. 21	9	17
39	..do.....	Aug. 16	Aug. 27	11	23
40	..do.....	Aug. 25	Sept. 5	11	32
41	Aug. 5	Aug. 11	Aug. 20	9	15
42	..do.....	Aug. 13	Aug. 21	8	16
43	..do.....	..do.....	Aug. 22	9	17
44	Aug. 6	Aug. 10	Aug. 18	8	12
45	..do.....	Aug. 14	Aug. 23	9	17
46	Aug. 7	Aug. 13	..do.....	10	16
47	..do.....	Aug. 15	Aug. 25	10	18
48	..do.....	Aug. 16	Aug. 27	11	20
49	..do.....	Aug. 18	Aug. 28	10	21
50	..do.....	Aug. 21	Aug. 30	9	23
51	..do.....	..do.....	Sept. 1	11	25
52	Aug. 11	Aug. 17	Aug. 27	10	16
53	..do.....	Aug. 18	..do.....	9	16
54	..do.....	Aug. 19	Aug. 30	11	19
55	..do.....	Aug. 21	Aug. 31	10	20
56	Aug. 13	Aug. 18	Aug. 27	9	14
57	Aug. 14	Aug. 21	Aug. 31	10	17
58	Aug. 15	Aug. 31	Sept. 12	12	28
59	..do.....	Aug. 19	Aug. 28	9	13
60	..do.....	Aug. 26	Sept. 6	11	22
61	Aug. 16	Aug. 24	Sept. 3	10	18
62	..do.....	..do.....	Sept. 5	12	20
63	..do.....	Aug. 25	Sept. 6	12	21
64	Aug. 17	Aug. 20	Aug. 30	10	13
65	..do.....	Aug. 29	Sept. 8	10	22
66	..do.....	Aug. 30	Sept. 10	11	24
67	Aug. 19	Aug. 25	Sept. 6	12	18
68	..do	Aug. 30	Sept. 11	12	23
69	Aug. 20	Aug. 29	Sept. 10	12	21
70	..do	Sept. 6	Sept. 17	11	28
71	Aug. 21	Aug. 28	Sept. 10	13	20
72	Aug. 24	Sept. 14	Oct. 1	17	38
73	Aug. 25	Sept. 1	Sept. 12	11	18
74	Aug. 26	Sept. 8	Sept. 20	12	25
75	Aug. 27	Sept. 6	Sept. 16	10	20
76	Aug. 28	Sept. 1	Sept. 14	13	17
77	Aug. 30	Sept. 9	Sept. 20	11	21
78	Sept. 1	Sept. 13	Sept. 25	12	24

SECOND-BROOD MOTHS.

Moths of the second brood were obtained from reared material July 25. Moths emerged in abundance during August and in diminishing numbers throughout September. The last one to emerge out of doors appeared October 1.

The earliest moths of this brood were not obtained in sufficient numbers to get the first possible third-brood eggs. Oviposition in a cage began on August 5 by moths the first of which emerged July 30. The record of this cage is given in Table XV.

TABLE XV.—*Life of second-brood moths (Cage IV), reared from second-brood larvæ recorded in Table XI.*

Moths emerged and put into cage.		Eggs laid (at night).		Moths died.	
Date.	Number.	Date.	Number.	Date.	Number.
July 30	1	August 5	2	August 9	(female) 1
July 31	1	August 6	2	August 10	(female) 1
August 2	1	August 8	55	August 11	(female) 2
August 3	3	August 9	54	August 12	(female) 2
August 4	2			do	(male) 1
August 6	1			August 13	(male) 1
August 7	3			Lost or escaped	5
August 11	1				
Total	13				

LENGTH OF LIFE CYCLE OF SECOND GENERATION.

The interval between the emergence of the earliest first-brood moth (June 8) and the earliest of the second brood (July 25) gives a period of 47 days for the life cycle. Records of 19 individuals, the larvæ being reared in bagged fruit on trees, give an average of 49.5 days from oviposition to emergence. Adding 5 days as the interval from emergence to oviposition gives 54.5 days as the total for the generation. The minimum time thus shown was 45 and the maximum 67 days. Records of these 19 individuals are given in Table XVI.

TABLE XVI.—*Records, from oviposition to emergence of adult, of 19 individuals of the second generation reared from moths recorded in Table IX—larvæ reared in bagged fruit on trees.*

Individual No.	Egg laid (at night).	Egg hatched (at night).	Larva left fruit.	Larva pupated.	Moth emerged.	Time from oviposition to emergence of adult.
						Days.
1	June 17	June 22	July 13	July 24	Aug. 2	46
2	...do	...do	July 14	July 17	July 27	40
3	...do	...do	...do	July 28	Aug. 6	50
4	...do	...do	...do	...do	Aug. 7	51
5	...do	...do	...do	July 31	Aug. 10	54
6	...do	...do	July 15	July 29	Aug. 7	51
7	...do	...do	July 16	July 25	Aug. 3	47
8	...do	...do	...do	...do	...do	47
9	...do	...do	...do	July 22	July 30	43
10	...do	...do	...do	July 28	Aug. 7	51
11	...do	...do	July 17	Aug. 2	Aug. 11	55
12	...do	...do	July 18	July 22	July 31	44
13	...do	...do	...do	July 26	Aug. 4	48
14	...do	...do	July 19	...do	Aug. 3	47
15	...do	...do	July 20	Aug. 7	Aug. 18	62
16	...do	...do	July 23	Aug. 4	Aug. 16	60
17	...do	...do	Transformed in fruit.		Aug. 4	48
18	...do	...do	.....do		...do	48
19	...do	...do	.....do		Aug. 5	49

Eleven individuals from the same lot as the above were reared in picked fruit in jars out of doors, and show an average of 42.3 days from oviposition to emergence, which would indicate about 47 days as the length of the life cycle. The records are shown in Table XVII.

TABLE XVII.—*Records, from oviposition to emergence of adult, of 11 individuals of the second generation reared from moths recorded in Table IX—larvæ reared in picked fruit, in jars out of doors.*

Individual No.	Egg laid (at night).	Egg hatched (at night).	Larva left fruit.	Larva pupated.	Moth emerged.	Time from oviposition to emergence of adult.
						Days.
1	June 17	June 22	July 13	July 21	July 31	44
2	...do	...do	July 14	July 17	July 28	41
3	...do	...do	...do	July 20	July 31	44
4	...do	...do	Transformed in fruit.		July 25	38
5	...do	...do	.....do		July 26	39
6	...do	...do	.....do		July 28	41
7	...do	...do	.....do		July 30	43
8	...do	...do	.....do		July 31	44
9	...do	...do	.....do		July 26	39
10	...do	...do	.....do		Aug. 2	46
11	...do	...do	.....do		...do	46

In 1907 records of 30 individuals reared in picked fruit in the laboratory gave a minimum time from oviposition to adult of 34 days, maximum 68, average 39.1 days. Allowing 5 days between emergence and oviposition, the length of the life cycle would be: Minimum, 39; maximum, 73; average, 49 days. These indoor records show an average life cycle 5 days shorter than the outdoor records (on bagged fruit) of 1908. Table XVIII gives a record of the 1907 rearings.

TABLE XVIII.—*Records from oviposition to emergence of adult of 30 individuals of the second generation reared in 1907 from larvæ and pupæ of the first generation collected from bands—material kept in laboratory.*

Individual No.	Egg laid.	Egg hatched.	Larva left fruit.	Moth emerged.	Time from oviposition to emergence of adult.
					Days.
1	July 5	July 10	July 27	Aug. 15	41
2	...do	...do	...do	Aug. 12	38
3	...do	...do	July 29	...do	38
4	...do	...do	...do	...do	38
5	July 10	July 15	July 30	Aug. 15	36
6	...do	...do	July 31	Aug. 13	34
7	...do	...do	...do	Aug. 14	35
8	...do	...do	Aug. 1	...do	35
9	...do	...do	...do	...do	35
10	...do	...do	...do	...do	35
11	...do	...do	...do	...do	35
12	...do	...do	...do	...do	35
13	...do	...do	...do	Aug. 16	37
14	...do	...do	...do	...do	37
15	...do	...do	...do	Aug. 25	46
16	...do	...do	Aug. 2	Aug. 15	36
17	...do	...do	...do	...do	36
18	...do	...do	...do	...do	36
19	...do	...do	...do	Aug. 21	42
20	...do	...do	...do	Aug. 22	43
21	...do	...do	...do	Aug. 27	48
22	...do	...do	Aug. 3	Aug. 15	36
23	...do	...do	...do	...do	36
24	...do	...do	...do	Aug. 16	37
25	...do	...do	...do	...do	37
26	...do	...do	...do	Sept. 16	68
27	...do	...do	Aug. 4	Aug. 17	38
28	...do	...do	Aug. 5	Sept. 1	53
29	...do	...do	(a)	Aug. 15	36
30	...do	...do	(a)	...do	36

a Spun cocoon in fruit.

THE THIRD GENERATION.

THIRD-BROOD EGGS.

In the cages third-brood eggs were first secured August 5. The calculated time for their first appearance in the field is 10 days earlier. The last eggs observed were laid in a cage October 16 by moths emerging up to October 1.

All second-brood and third-brood eggs laid before August 28 hatched in 5 days, the usual summer incubation period. During September the egg stage was gradually lengthened toward the maximum period shown in early spring eggs. The eggs from which the third-brood larvæ were reared incubated as shown in Table XIX.

TABLE XIX.—*Incubation periods of third-brood eggs laid in Cage IV (recorded in Table XV).*

Number of eggs.	Eggs laid (at night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
55	Aug. 8	Aug. 11	Aug. 13	Aug. 14, a. m.	5
54	Aug. 9	Aug. 12	Aug. 14, a. m.	Aug. 14, night	5

Records of other eggs, mostly of the third brood, laid throughout the latter part of the season are given in Table XX.

TABLE XX.—*Incubation periods of miscellaneous second-brood and third-brood eggs.*

Number of eggs.	Eggs laid (at night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
94	July 30			Aug. 4, evening and night.	5
23	Aug. 12	Aug. 14, p. m.	Aug. 17, a. m.	Aug. 17, night	5
18	Aug. 13			Aug. 18, p. m.	5
96	Aug. 28	Aug. 30	Sept. 2	Sept. 3, p. m.	5½–6
50	Aug. 29	Aug. 31	Sept. 4	Sept. 5	6
46	Sept. 7	Sept. 9	Sept. 13, a. m.	Sept. 13, p. m. and night.	6
37	Sept. 11	Sept. 13	Sept. 16	Sept. 17, m.	5½
3	Sept. 17		Sept. 24, a. m.	Sept. 25, p. m. and night.	8
34	Sept. 23		Oct. 3	Oct. 5, a. m	11¼
16	Sept. 24–27			Oct. 9–15	14–18
4	Oct. 16	Oct. 18–19	Oct. 29	Dried up	13+

THIRD-BROOD LARVÆ.

In the cages the first hatching of third-brood larvæ was on August 14. Judging from the emergence of second-brood moths July 25, third-brood larvæ probably appeared in the field during the first week of August. Owing to the early dropping of the small crop of fruit in 1908, field observations on larvæ entering fruit could not be made during September. In the cages larvæ continued to hatch in numbers up to September 20, and the last on October 15. The last lot of eggs developed as far as the black-spot stage on October 29, but failed to hatch.

As the harvesting of the apple crop in this region ordinarily begins early in September, considerable numbers of the third brood would fail to mature before fruit picking. Reared larvæ of this brood began to mature September 2, and the band record for 1907 (p. 23) also shows an increase about this time. The calculated time of maturing of the earliest third-brood larvæ in 1908 is August 20. Owing to the dropping of the fruit in 1908, the band record for this season (p. 24) does not include a normal number of the later larvæ. In 1907 larvæ spun cocoons under the bands as long as any apples were on the trees, and at harvest time many small worms were still in the fruit.

Forty-one third-brood larvæ, hatching August 14 and reared in picked fruit in jars out of doors, required from 19 to 32 days to become full grown, the average being slightly over 24 days. These records are given in Table XXI.

TABLE XXI.—*Life of third-brood larvæ, reared in picked fruit in jars out of doors, from eggs recorded in Table XIX.*

Number of larvæ.	When hatched.	Date of leaving fruit.	Time in fruit.
			Days.
2	Aug. 14, a. m.	Sept. 2	19
2	.....do	Sept. 3	20
1	.....do	Sept. 4	21
3	.....do	Sept. 5	22
8	.....do	Sept. 7	24
3	.....do	Sept. 8	25
2	.....do	Sept. 9	26
1	.....do	Sept. 11	28
1	.....do	Sept. 12	29
1	.....do	Sept. 14	31
1	.....do	Sept. 15	32
1	Aug. 14, night.	Sept. 3	19
2	.....do	Sept. 4	20
2	.....do	Sept. 5	21
1	.....do	Sept. 6	22
3	.....do	Sept. 7	23
2	.....do	Sept. 8	24
1	.....do	Sept. 11	27
1	.....do	Sept. 12	28
2	.....do	Sept. 14	30
1	.....do	Sept. 15	31

Total number, 41.

All reared larvæ of the third brood were of the wintering generation.

WINTERING LARVÆ.

A few erratic larvæ maturing early in the season failed to pupate. They remained in their cocoons throughout the season, apparently in a perfectly healthy condition. The first of these left the fruit June 9 and was undoubtedly of the first brood. Two others leaving the fruit July 2 and 4 were also probably of this brood. One wintering larva left the fruit July 10, two July 19, and one August 2. All the above larvæ were from collected wormy fruit. Among 20 of the earlier second-brood larvæ reared in bagged fruit (Table XXVI), 1 wintering larva left the fruit July 19. In 1907, out of 41 second-brood larvæ reared in the laboratory (Table XXIX), 5 that did not pupate left the fruit August 1–6.

Beginning August 20, the percentage of wintering larvæ leaving the fruit suddenly arose to include the majority. In 1907 this happened about the same time. A record of the material collected in taking the band records at this period will illustrate the transition. This is shown in Tables XXII and XXIII.

TABLE XXII.—*Transition to wintering larvæ in 1907.*

Larvæ forming cocoons under bands.	Number pupating.	Number wintering.
July 22–29	112	1
July 29–August 5	193	1
August 5–12	144	4
August 12–19	121	36
August 19–26	50	46
August 26–September 2	8	36
September 2–9	0	52

TABLE XXIII.—*Transition to wintering larvæ in 1908.*

[From record made by Mr. S. W. Foster.]

Larvæ forming cocoons under bands.	Number pupating.	Number wintering.
July 13–20	15	1
July 20–27	26	0
July 27–August 3	27	1
August 3–10	63	6
August 10–17	16	6
August 17–24	11	12
August 24–31	1	5
August 31–September 7	0	11

After September 1 all larvæ appearing under bands were of the wintering brood. While some of the later second-brood larvæ may go over winter, there is evidence that most of them produce a second brood of moths instead. The species is therefore dependent largely upon the third-brood larvæ to perpetuate itself from season to season.

Conditions affecting wintering larvæ in the orchard were not observed. Around the out door apple bin at a vinegar factory where large numbers of cocoons were examined in March and April the great majority of them contained live larvæ or pupæ.

REVIEW OF REARING WORK OF THE SEASON.

An effort was made to rear through the season a continuous line of pedigreed stock from the earliest spring moths, with the principal object of ascertaining the maximum number of generations. With the exception of one unimportant break early in the season, this program was successfully carried out.

The start was made from a number of eggs collected in the field and hatching May 4, several days before the hatching of the first eggs laid in cages. The larvæ were reared in bagged fruit on trees, and developed into first-brood adults as shown in Table XXIV.

TABLE XXIV.—*Records, from hatching of egg to emergence of adult, of 4 individuals of the first generation. (Reared from first eggs found in orchard.)*

Egg hatched.	Larva left fruit.	Larva pupated.	Moth emerged.
May 4....	May 26	May 30	June 8
Do.....	May 27	May 31	June 9
Do.....	May 28	June 1	June 13
Do.....	May 29	June 2	June 12

Not enough adults were obtained in this rearing to insure oviposition for the second generation, so other adults reared from the earliest wormy apples from the orchard were put into the cage. This is the only break in the line of descent, where outside material had to be added. However, there can be no doubt that all these moths were of the first brood. In Table XXV is given the record of oviposition of these moths.

TABLE XXV.—*Life of moths of first brood, reared from first-brood larvæ from earliest wormy apples collected in orchard, and from earliest larvæ reared in bagged fruit.*

Moths emerged and put into cage.		Eggs laid (at night).		Moths died.	
Date.	Number.	Date.	Number.	Date.	Number.
June 8..................	1	June 13................	2	June 16................	1
June 9..................	1	June 14................	16	June 18................	1
June 11..................	1	June 15................	26	June 19................	7
June 12..................	5	June 16................	18	June 21................	7
June 14..................	2	June 17................	104	Escaped................	5
June 15..................	11	June 18................	25		

While not the earliest, the eggs laid on the night of June 17 were selected, on account of their numbers, to start the second generation. Some of the larvæ hatching from these eggs were put on bagged fruit, and others were reared in picked fruit kept out of doors in jars. Those on bagged fruit developed as shown in Table XXVI.

TABLE XXVI.—*Records, from oviposition to emergence of adult, of 20 individuals of the second generation, reared from moths recorded in Table XXV—larvæ reared in bagged fruit on trees.*

Individual No.	Egg hatched (at night).	Larva transferred to bagged fruit.	Larva left fruit.	Larva pupated.	Moth emerged.
1..................	June 22	June 25	July 13	July 24	Aug. 2
2..................	...do.....	...do.....	July 14	July 17	July 27
3..................	...do.....	...do.....	...do.....	July 28	Aug. 6
4..................	...do.....	...do.....	...do.....	...do.....	Aug. 7
5..................	...do.....	...do.....	...do.....	July 31	Aug. 10
6..................	...do.....	...do.....	July 15	July 29	Aug. 7
7..................	...do.....	...do.....	July 16	July 25	Aug. 3
8..................	...do.....	...do.....	...do.....	...do.....	Do.
9..................	...do.....	...do.....	...do.....	July 22	July 30
10..................	...do.....	...do.....	...do.....	July 28	Aug. 7
11..................	...do.....	...do.....	July 17	Aug. 2	Aug. 11
12..................	...do.....	...do.....	July 18	July 22	July 31
13..................	...do.....	...do.....	...do.....	July 26	Aug. 4
14..................	...do.....	...do.....	July 19	...do.....	Aug. 3
15..................	...do.....	...do.....	July 20	Aug. 7	Aug. 18
16..................	...do.....	...do.....	July 23	Aug. 4	Aug. 16
17..................	...do.....	...do.....	Transformed in fruit.		Aug. 4
18..................	...do.....	...do.....	..........do..........		Do.
19..................	...do.....	...do.....	..........do..........		Aug. 5
20..................	...do.....	...do.....	July 19	Wintering.	

To secure third-brood eggs, only moths that developed from the second-brood larvæ on bagged fruit were used. These emerged and oviposited as recorded in Table XXVII.

TABLE XXVII.—*Life of moths of second brood, reared from material recorded in Table XXVI.*

Moths emerged and put into cage.		Eggs laid (at night).		Moths died.	
Date.	Number.	Date.	Number.	Date.	Number.
July 30	1	August 5	2	August 9	(female) 1
July 31	1	August 6	2	August 10	(female) 1
August 2	1	August 8	55	August 11	(female) 2
August 3	3	August 9	54	August 12	(female) 2
August 4	2			Do	(male) 1
August 6	1			August 13	(male) 1
August 7	3				
August 11	1				
Total	13			Lost or escaped	5

The eggs laid August 8 and 9 developed a third brood of larvæ as shown in Table XXVIII.

TABLE XXVIII.—*Life of larvæ of third brood, reared from eggs recorded in Table XXVII.*

Eggs laid (at night).	Eggs hatched.	Number of larvæ.	Larvæ left fruit.
Aug. 8	Aug. 14, a. m.	2	Sept. 2
Do	do	2	Sept. 3
Do	do	1	Sept. 4
Do	do	3	Sept. 5
Do	do	8	Sept. 7
Do	do	3	Sept. 8
Do	do	2	Sept. 9
Do	do	1	Sept. 11
Do	do	1	Sept. 12
Do	do	1	Sept. 14
Do	do	1	Sept. 15
Aug. 9	Aug. 14, night.	1	Sept. 3
Do	do	2	Sept. 4
Do	do	2	Sept. 5
Do	do	1	Sept. 6
Do	do	3	Sept. 7
Do	do	2	Sept. 8
Do	do	1	Sept. 11
Do	do	1	Sept. 12
Do	do	2	Sept. 14
Do	do	1	Sept. 15

The above larvæ were reared out of doors in picked fruit. All of them were of the wintering generation.

THIRD GENERATION IN 1907.

In 1907 all the rearing was done in the laboratory. The first larvæ and pupæ collected in taking the band record (first generation) were used to begin rearing for a third generation. From this material first-brood moths began to emerge June 25. Second-brood eggs were laid by them in large numbers July 5 to 20, from which 41 second-brood larvæ developed as shown in Table XXIX.

TABLE XXIX.—*Records of 41 individuals of the second generation, reared in the laboratory in 1907, from band-collected larvæ and pupæ of the first generation.*

Number of individuals.	Eggs hatched.	Larvæ left fruit.	Moths emerged.	Number of individuals.	Eggs hatched.	Larvæ left fruit.	Moths emerged.
1	July 10	July 27	Aug. 15.	2	July 15	Aug. 3	Aug. 15.
1	...do.....	...do.....	Aug. 12.	1	...do.....	...do.....	Aug. 16.
2	...do.....	July 29	Do.	1	...do.....	...do.....	Do.
1	...do.....	July 30	Pupa died.	1	...do.....	...do.....	Sept. 16.
1	July 15	...do.....	Aug. 15.	1	...do.....	Aug. 4	Aug. 17.
1	...do.....	July 31	Aug. 13.	1	....	...do.....	Aug. 16.
1	...do.....	...do.....	Aug. 14.	1	....	...do.....	Wintering.
5	...do.....	Aug. 1	Do.	1	....	...do.....	Aug. 15.
1	...do.....	...do.....	Aug. 16.	1	July 15	Aug. 5	Sept. 1.
1	...do.....	...do.....	Do.	1	...do.....	...do.....	Wintering.
1	...do.....	...do.....	Aug. 25.	1	...do.....	Aug. 6	Do.
3	...do.....	Aug. 2	Aug. 15.	1	...do.....	...do.....	Do.
1	...do.....	...do.....	Aug. 21.	1	....	Aug. 7	Aug. 18.
1	...do.....	...do.....	Aug. 22.	1	....	...do.....	Aug. 20.
1	...do.....	Aug. 1	Wintering.	1	....	Aug. 9	Aug. 25.
1	...do.....	Aug. 2	Aug. 27.	2	July 15	(a)	Aug. 15.

a Pupated in fruit.

As indicated in the table, 5 of these larvæ lived over winter, while the others developed to second-brood moths. No attempt was made to secure third-brood eggs from these moths, but from the time of their emergence we should expect third-brood larvæ to begin hatching about August 20.

MISCELLANEOUS OBSERVATIONS.

BAND RECORDS.

A band record is an important aid in tracing the seasonal history of the codling moth. The band record for 1907 is given in Table XXX and is shown graphically in figure 2.

TABLE XXX.—*Band record of 1907, made from 25 trees in an unsprayed orchard.*

Date.	Number of larvæ and pupæ taken from bands.	Date.	Number of larvæ and pupæ taken from bands.
June 3	0	August 5	212
June 10	0	August 12	168
June 17	28	August 19	170
June 24	48	August 26	98
July 1	25	September 2	46
July 8	47	September 9	52
July 15	56	September 16	67
July 22	75	October 7	156
July 29	131		

The gap between the first-brood and the second-brood larvæ, indicated in the 1907 band record at July 1, should have come a week or more later. The week ending July 1 was cool and very rainy, the bands being continuously wet. This must have delayed many larvæ in leaving the fruit, and prevented others from selecting the bands as a place for spinning their cocoons.

The third brood shown in the 1907 band record (beginning September 2) is probably normal in bulk, though the curve should perhaps rise more abruptly and stop earlier at the date of harvesting the apples. There were taken October 7 from the bands 156 larvæ, an average of 52 per week since the last previous examination; meanwhile the fruit had been gathered, but the exact date could not be ascertained. Picking the fruit would of course put an end to the band record.

It will be noticed in the curve (fig. 2) that the second brood is many times larger than the first. But the third brood, instead of showing a further increase, is scarcely larger than the first. This is not to be taken as evidence of only a partial brood, but is due to the fact that the fruit was harvested before the bulk of the third brood had matured.

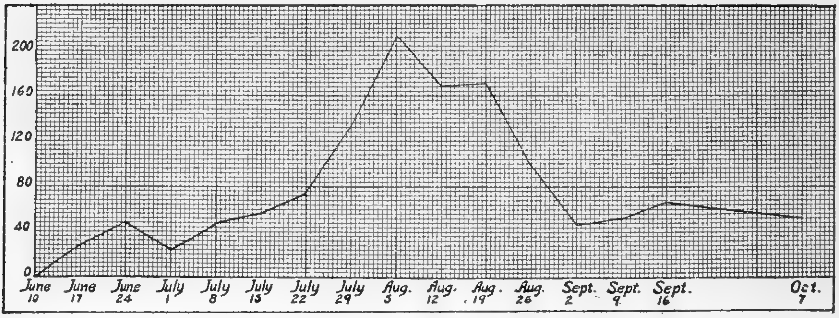

FIG. 2.—Curve showing record of larvæ and pupæ of the codling moth taken from bands in 1907.

The 1908 band record (Table XXXI and fig. 3) was influenced by the very smal' size of the apple crop in that year.

TABLE XXXI.—*Band record of 1908, made from 18 trees in an orchard sprayed once after the calices had closed.*

[Record by Mr. S. W. Foster.]

Date.	Number of larvæ and pupæ taken from bands.	Date.	Number of larvæ and pupæ taken from bands.
June 6–15	62	August 3	28
June 22	45	August 10	69
June 29	67	August 17	30
July 6	66	August 24	23
July 13	31	August 31	6
July 20	16	September 7	11
July 27	26	September 14	2

The trees from which this record was made had lost all their fruit by September 7.

In the 1908 band record the smaller size of the second brood as compared with the first is due to the fact that the very small crop of apples became so infested that they fell from the trees before a large number of the later larvæ had matured. For the same reason the

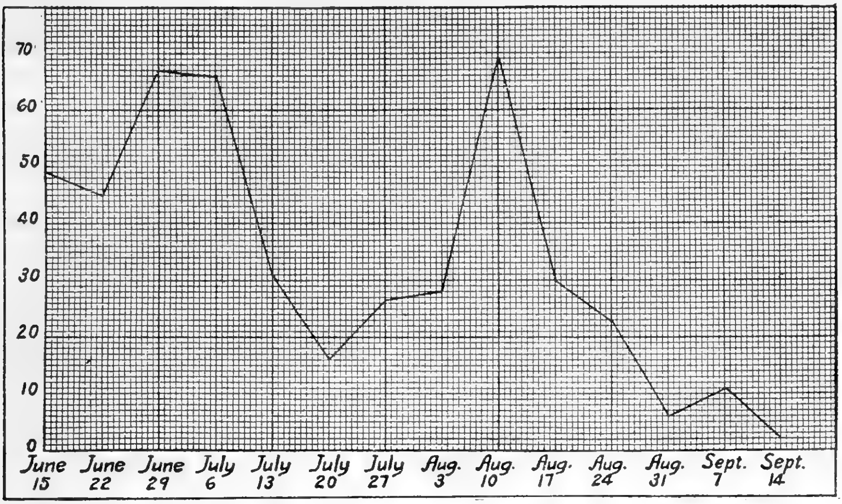

FIG. 3.—Curve showing band record of 1908.

third brood is not represented. The record was not begun in time to include the earliest larvæ, which had begun to leave the fruit May 24.

A band record made in 1908 by Mr. F. W. Faurot (figs. 4 and 5) at Anderson, Mo., 40 miles north of Siloam Springs, is interesting

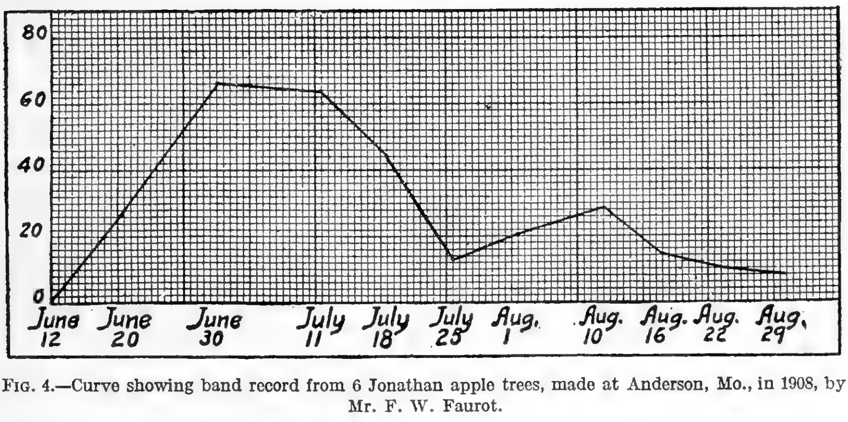

FIG. 4.—Curve showing band record from 6 Jonathan apple trees, made at Anderson, Mo., in 1908, by Mr. F. W. Faurot.

as showing the effect of spraying. The record was made on unsprayed trees in a sprayed orchard. Since the banded trees were themselves not sprayed, the size of the first brood of larvæ shown in the band record was not affected. But the spraying of the remainder of the orchard, and the killing of all larvæ and pupæ taken from the bands, caused a marked reduction, instead of the normal increase, in the size of the second brood.

The part of this record from 6 Jonathan trees, from which the fruit was picked the last of August, thus shutting out the third brood, is separated from the remainder. Figure 4 shows the record from these trees, and figure 5 the remainder of the record, taken from 5 Gano and 9 Lansingburg trees, the latter a very late variety.

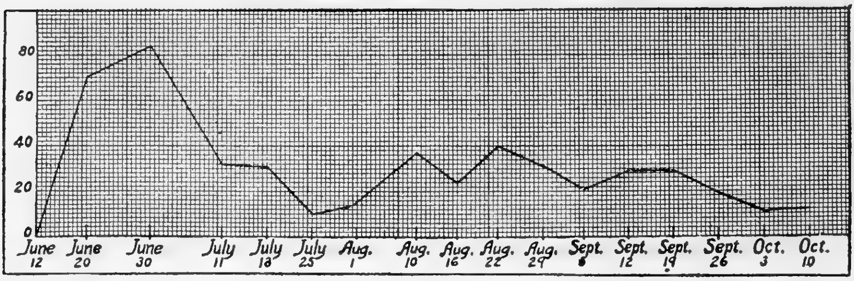

FIG. 5.—Curve showing band record from 14 Gano and Lansingburg apple trees, made at Anderson, Mo., in 1908, by Mr. F. W. Faurot.

EMERGENCE OF MOTHS.

All larvæ and pupæ collected in taking the band records at Siloam Springs were kept in muslin-covered jars, in order to record the issuing of adults. The material of 1907 was kept in the laboratory, and that of 1908 out of doors. Weekly summaries of the emergence of the moths are given in Tables XXXII and XXXIII and in figures 6 and 7.

TABLE XXXII.—*Laboratory record of emergence of adults from material collected in taking band record in 1907.*

Date.	Number of moths emerging.	Date.	Number of moths emerging.
June 28–July 4	23	August 15–22	113
July 4–11	16	August 22–29	111
July 11–18	29	August 29–September 5	58
July 18–25	29	September 5–12	13
July 25–August 1	39	September 12–19	2
August 1–8	48	September 20	1
August 8–15	176	October 4	1

TABLE XXXIII.—*Outdoor record of emergence of adults from material collected in taking band record in 1908.*

[Records by Mr. S. W. Foster.]

Date.	Number of moths emerging.	Date.	Number of moths emerging.
June 22–29	18	August 2–8	2
June 29–July 6	43	August 8–15	22
July 6–13	40	August 15–22	23
July 13–20	38	August 22–29	31
July 20–27	40	August 29–September 5	6
July 27–August 2	38	September 5–12	2

It will be noticed that the curves illustrating the emergence records follow closely the contour of the corresponding band-record curves, as far as the first and the second broods are concerned. The third brood is, of course, not represented in the emergence records. A record of the emergence of the third brood of 1907 (spring brood of 1908) is given on page 5, figure 1.

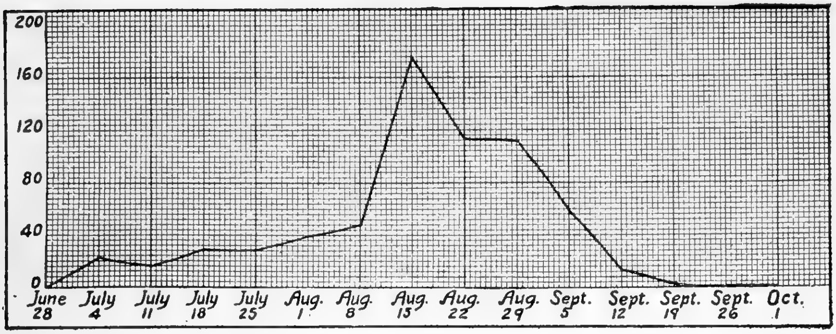

FIG. 6.—Curve showing emergence of adults from material collected in taking band record in 1907.

The ratio in size of the second brood of adults to the second brood of larvæ is practically the same as between the first-brood adults and the first-brood larvæ, shown in the emergence and the band records, respectively. This shows that as large a proportion of the second-brood as of the first-brood larvæ transform to adults; which is evidence that there is nearly a full third brood.

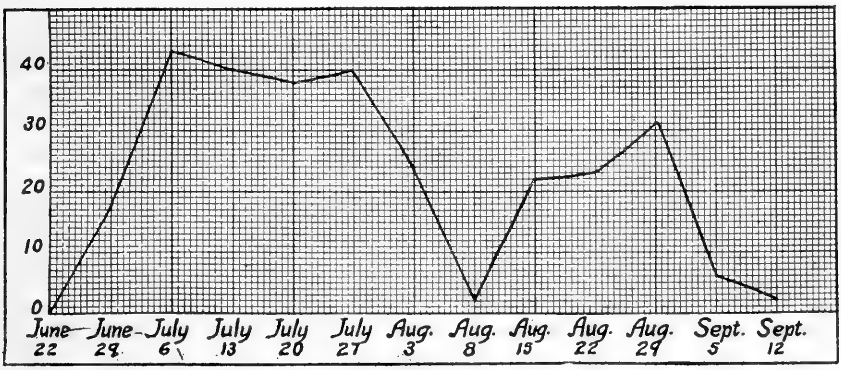

FIG. 7.—Curve showing emergence of adults from material collected in taking band record in 1908.

LARVÆ ON FOLIAGE.

Two larvæ just hatched were inclosed in paper bags on water sprouts May 4. The twigs were not examined again until May 29. In each case there was evidence of work by the larvæ. On one twig the feeding was confined to a leaf, but on the other four the young larvæ had bored down the tender end of the sprout from half an inch to 2 inches. No remains of the larvæ could be found. They had apparently bored down the twigs until they encountered wood too hard for them to chew, when they left the burrows and were lost.

In the laboratory four larvæ just hatched were put on foliage May 7. The ends of the twigs were stuck into a bottle of water, cotton was stuffed around the neck of the bottle, and the whole put under a bell jar. Two larvæ were working May 12. On May 23 one larva was still feeding. It had begun work on a leaf, then it bored into the midrib and through the petiole into the end of the twig. The larva was transferred to a fresh twig, and when again examined, May 29, had burrowed for a distance of 1¼ inches. Then it had left the burrow, and forcing its way through the cotton at the neck of the bottle had drowned itself therein. It had reached a length of 9.5 millimeters and appeared to have passed the fifth molt.

LARVÆ IN PEACHES.

Two peaches containing codling-moth larvæ were collected in the orchard, on trees adjoining an apple orchard. Both peaches ripened several days before the larvæ left them. One larva issued July 28 from a peach collected July 10. The adult emerged August 10. Another peach collected July 29 gave out a larva on August 2, from which the adult emerged August 16.

NUMEROUS LARVÆ IN ONE APPLE.

Throughout the season, and also in 1907, it was noticed that when large numbers of young larvæ were allowed to enter a single apple at the same time, only a few survived. If larvæ being reared from eggs laid in cages were not transferred to separate fruits within three to five days after hatching, or before their burrows reached the core, only a small proportion of the number entering could be accounted for.

Some third-brood larvæ entering fruit in cages were left undisturbed, the apples being kept in jars out of doors. The results, given in Table XXXIV, show that more than one larva is not likely to reach maturity in a single fruit at the same time.

TABLE XXXIV.—*Record of maturing larvæ from 4 apples, each infested at the same time by numerous larvæ.*

Eggs hatched.	Number of larvæ entering apple.	Larvæ formed cocoons.		Number of larvæ maturing.
		Date.	Number.	
Aug. 14..	18	Sept 5	1	1
Do.....	11	Sept. 5; spun cocoon in fruit.	1 1	2
Sept. 14..	18	Oct. 20	1	1
Do.....	8	...do....	1	1

NUMBER OF MOLTS.

A large number of larvæ were reared separately in pieces of apple in vials. Immediately after hatching they were transferred to the vials, and were examined daily, or at least every second day. At each examination they were changed to fresh food.

Either the frequent disturbance or the lack of apple seeds in their diet caused the larvæ to develop very slowly and to become dwarfed. The mature larvæ were very much undersized, and some of the moths that developed from them were scarcely larger than adults of the lesser apple worm (*Enarmonia prunivora* Walsh).

The normal number of molts is apparently 6 (7 instars), though 3 of the 12 larvæ that reached maturity molted 7 times (8 instars). The period of development was so much lengthened and the larvæ were so dwarfed that no conclusions can be given as to the normal length of the various instars or the size of the larva in each.

In Table XXXV are given the individual records (omitting measurements) of the 12 larvæ that reached maturity.

TABLE XXXV.—*Number of molts of the codling moth—laboratory observations on larvæ reared in pieces of apple in vials.*

Individual No.	When hatched.	Molts.							Larva formed cocoon.
		I.	II.	III.	IV.	V.	VI.	VII.	
1	Aug. 17	Aug. 21		Sept. 2	Sept. 9	Sept. 16	Sept. 26		Oct. 13
2	...do...		Aug. 28	Sept. 1	Sept. 7	Sept. 14	Sept. 21		Oct. 6
3	...do...	Aug. 23	Aug. 29	Sept. 4	Sept. 10	Sept. 16	Sept. 27		Oct. 15
4	...do...	...do...		Sept. 2	Sept. 8	Sept. 19			Oct. 7
5	...do...	Aug. 24	Aug. 29	Sept. 4	Sept. 11	Sept. 17	Sept. 27		Oct. 16
6	...do...	Aug. 23	Aug. 28	Sept. 1	Sept. 8	...do...	Sept. 30	Oct. 19	Oct. 26
7	Aug. 18	Aug. 24	Aug. 29	Sept. 3	Sept. 10	Sept. 19	Oct. 3		Oct. 21
8	Sept. 3	Sept. 9	Sept. 14	Sept. 21	Sept. 29	Oct. 13	Oct. 30	Nov. 20	Dec. 4
9	...do...	...do...	...do...		Oct. 2	Oct. 11	Oct. 23	Nov. 9	Dec. 2
10	...do...	Sept. 8	Sept. 15		Sept. 29	Oct. 13	Oct. 25		Nov. 20
11	...do...	Sept. 9	...do...		Oct. 2	Oct. 15	Oct. 28		Nov. 27
12	...do...	Sept. 8	Sept. 13	Sept. 20	Sept. 28	...do...	Oct. 25		Nov. 17

NATURAL ENEMIES.

On May 6, while bagging fruit and collecting codling-moth eggs, about a dozen specimens of a red mite (determined by Mr. N. Banks as *Trombidium* sp.) were observed crawling about the twigs and leaves. By accident one of them got into the box of collected codling-moth eggs on leaves. On examining the eggs in the laboratory later, the mite was found in the act of eating one of them. The egg upon which it was operating was in the black-spot stage. When the mite had finished, the egg had the appearance of having hatched, except that the black head and cervical shield of the embryo remained visible underneath the egg shell. The mite was then allowed to attack a larva that was just issuing from the egg, having crawled nearly all the way out. When examined three hours later, nothing was left of the larva but the head and shriveled skin. This mite was later found to be fairly common on other trees as well as apple.

Two species of ants, *Solenopsis validiusculus* Emery and *Cremastogaster bicolor* Buckley as determined by Mr. Theo. Pergande, were frequently found attacking live larvæ under bands.

An ichneumon, determined by Mr. J. C. Crawford as the commonly recorded parasite of the codling moth, *Pimpla annulipes* Brullé, was frequently reared from band-collected material. From one lot of larvæ taken from the bands, Mr. S. W. Foster reared 11 specimens of an undetermined chalcidid, possibly a secondary parasite.

Two specimens of a small tachina fly, *Tachinophyto* sp.? (determined by Mr. C. H. T. Townsend), were reared in 1907. One individual issued from a larva which was brought into the laboratory while still in the apple, though nearly full grown.

PERCENTAGE OF FRUIT INFESTED.

In 1908 the apple crop was so small that the growers did not consider it worth protecting by spraying. On account of the small crop and the lack of preventive measures, practically every apple was wormy and the fruit fell from the trees before a large number of the later larvæ had a chance to enter. In 1907, counts from 8 unsprayed trees (4 Ben Davis and 4 Winesap) showed a percentage of wormy fruit varying from 48.1 to 64.1, the average on the Winesaps being 50.7 and on the Ben Davis 60.4. A total of 20,890 apples were examined from the 8 trees, including all windfalls throughout the season. Apples infested with codling moth, *Enarmonia prunivora* Walsh, and *Epinotia pyricolana* Murtfeldt were classed together as "wormy" fruit. Curculio injury was disregarded.

So small a percentage of infestation seems rather remarkable in a locality such as this, where at least a majority of the insects pass through three generations, while in other fruit-growing districts with a shorter season an unprotected apple crop is completely destroyed by the codling moth. Perhaps the third generation may be a disadvantage in the increase of the insect, as a considerable proportion of this brood, being yet in the fruit when the crop is harvested, is removed from the orchard (see 1907 band record, p. 23). And it must be that many of the later larvæ to hatch would even fail to find any fruit to enter, as the apple harvest usually begins early in September.

CONCLUSIONS.

Three generations of larvæ of the codling moth occur in the Ozarks of northern Arkansas, and most of the members of the second generation develop into adults.

The date at which larvæ begin to enter the fruit, relative to the blossoming of apple trees, is susceptible to great variation on account of weather conditions. In the two seasons under observation the interval was 6 and 3 weeks, respectively, between the falling of apple blossoms and the hatching of the first larvæ.

There is a sufficient interval between the first brood and the second brood of larvæ to be noticeable in the field; so that members of the two broods, though present together, may be distinguished by their size in most cases.

The third brood of larvæ constitutes the greater part of the wintering brood. Since the principal varieties of apples are harvested in this region while considerable numbers of the third brood of larvæ are yet immature, the number of larvæ wintering in the orchard is materially reduced. A smaller percentage of fruit is infested by the codling moth in this locality than in many places where only two generations are developed.

A summary of the seasonal history of the insect for the year 1908, as detailed in the preceding pages, is shown diagrammatically in figure 8.

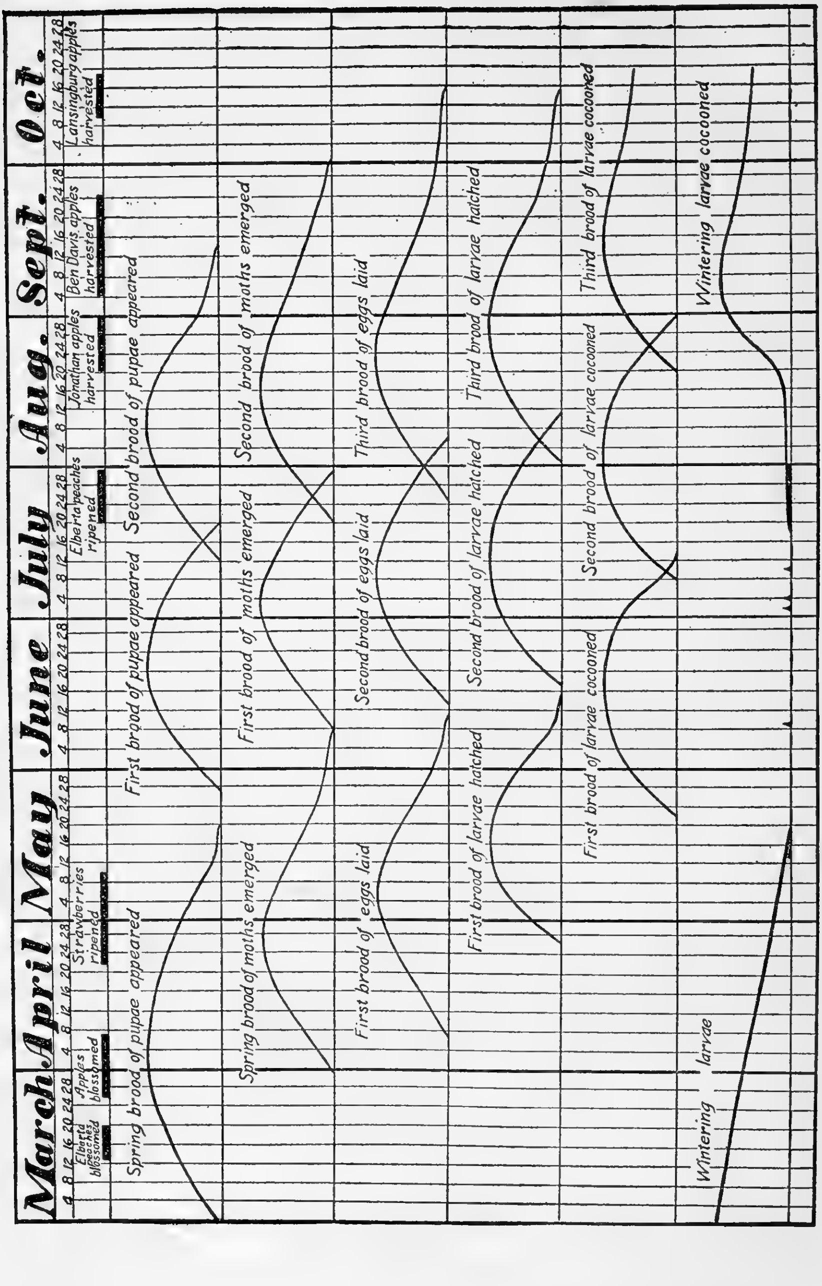

FIG. 8.—Diagram illustrating the seasonal history of the codling moth as observed in 1908 at Siloam Springs, Ark.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CIGAR CASE-BEARER.

(*Coleophora fletcherella* Fernald.)

By A. G. Hammar,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the past several years the cigar case-bearer (*Coleophora fletcherella* Fernald) has occasionally come to notice on account of the injuries inflicted by it on the foliage and fruit of apple and pear trees, especially the former.

Although apparently common in different sections of the country its presence is readily overlooked, owing to its small size and the concealed life of the larva. When occurring in large numbers it first attracts attention during May and June, at which time the insect is most active and feeding freely upon the foliage. The larva itself is in a small cylindrical or cigar-shaped case, which is composed of a portion of the skin of the leaf.

In its feeding habits the larva is, to a certain extent, a miner. It always carries its case for protection, however, protruding from it when feeding. Upon close observation of the feeding marks on the foliage it will be found that they consist of a more or less round undermined area, from which the parenchyma has been removed, with a minute circular hole through the skin of the leaf, through which the larva made its entrance. By these markings on the leaves and by the cigar-shaped cases (fig. 9) of the larva the insect is readily distinguished from other related orchard pests. The cigar case-bearer has occasionally proved itself capable of destroying the foliage of entire orchards. Crop failures and various deformities of the fruit have also been ascribed to this insect.

HISTORY.

The attention of entomologists was first called to the destructiveness of the cigar case-bearer in 1888, when Mr. P. Barry, of Rochester, N. Y., found the larvæ feeding upon the young fruit of pears. Specimens of the insect were sent to Dr. J. A. Lintner, as recorded in his Fifth Report, page 324 (1889). Based upon the information and studies of the living material received from Mr. Barry, Doctor Lintner later gave an account of the insect before the Western New York Horticultural Society in 1890, under the title, "A New Pear Insect, *Coleophora* sp.," with a brief description of the insect and its life history and recommending an arsenical spray for its control in case it should appear in injurious numbers. Later the same account was reprinted in Popular Gardening for 1890, and in 1891 it was included in Doctor Lintner's seventh report as state entomologist of New York.

About the same time as noted in the Rochester occurrence, the insect attracted attention in orchards in Canada. Dr. James Fletcher in 1889 received some larvæ from Charlestown, Prince Edward Island, which were found feeding on plum trees. Soon after they were also found depredating upon apple and pear. In 1891 Dr. D. Young, of Adolphustown, Ontario, informed Doctor Fletcher of their abundance in orchards of that locality, and during the same year further reports of the insect came in from Port Williams, Nova Scotia. At Adolphustown Doctor Young carried out extensive spraying experiments with kerosene emulsion and Paris green. A full account of these and other experiments will be found in Fletcher's various publications from 1891 to 1894. Prof. C. H. Fernald, in 1892, described the new insect, naming it *fletcherella* in honor of Doctor Fletcher, who had submitted specimens for determination. He also mentions having received specimens from Lintner, who, in his ninth report (1893), showed that the case-bearer referred to in his earlier reports was this same species. Further notes on the insect in Canada were given by Fletcher in the Report of the Entomological Society of Ontario for 1894.

Prof. L. H. Bailey in 1895 reported that the failure of the apple crop in Wayne and Monroe counties, N. Y., was to a great extent due to the damages caused by the cigar case-bearer. The same year Professor Slingerland published a valuable account of the insect, giving a detailed description of it and of its life history, with excellent photographic illustrations and a full bibliography.

Prof. T. D. A. Cockerell in 1896 reported its introduction at Santa Fe, N. Mex., the young larvæ evidently having been brought in on infested nursery stock from the State of New York.

A hymenopterous parasite, *Microdus laticinctus* Ashm., was obtained by Fletcher from cases from Port Hope, Ontario.[a]

In 1898 Faville reported the occurrence of the insect at Manhattan, Kans., where for several years it had caused much injury.

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[a] Twenty-seventh Ann. Rep. Ent. Soc. Ont., 1897, p. 67.

A brief account of the life history of the insect is given by Dr. E. P. Felt in the Country Gentleman for November, 1901, and it is referred to by the same writer in his Illustrated Descriptive Catalogue of Some of the More Injurious and Beneficial Insects of New York State.[a]

Prof. S. A. Forbes in 1900 gave a brief note on a similar insect feeding on sugar beet. At the time this was supposed to be *C. fletcherella* Fernald, having very similar habits and appearance. Mr. August Busck, of this Bureau, however, has recently examined specimens sent by Professor Forbes and finds that they belong to a different species.

In 1902 it was included in Banks's Principal Insects Liable to be Distributed on Nursery Stock.[b] It is here recorded feeding upon pear and quince.

Specimens were received by Doctor Fletcher from Victoria, British Columbia, in 1905, and were sent by him to this Bureau for determination. The moths, which were examined by Mr. Busck, were found to be slightly smaller than those from New York or eastern Canada. Recently Mr. Busck has been kind enough to reexamine the specimens, and from a comparison of later collected material in the United States National Museum collection considers those from Victoria to be identical. The larvæ of the moths mentioned above were found feeding on hawthorn. The difference in size is probably due to local conditions and to the different food plant.

In a letter dated February 16, 1909, to this Bureau, Prof. R. H. Pettit, of the Michigan Agricultural College, states that he received specimens of the cigar case-bearer from Port Hope, Mich., where in 1908 it was reported as being quite a serious pest.

During the summer of 1908 the writer had the opportunity of studying the cigar case-bearer at North East, Pa. A small orchard of 40 or 50 trees belonging to Mr. A. L. Short was, in the early part of June, so badly infested by the insect that literally every leaf had been devoured.

Mr. R. W. Braucher, of this Bureau, during the summer of 1908 observed the insect at Douglas, Mich., where it was found more or less frequently in different orchards.

DISTRIBUTION.

The cigar case-bearer is evidently a native insect, feeding originally on crab apples and hawthorn. Although at present recorded only from scattered sections of the country, it is not improbable that it has a rather general distribution. In Canada, Fletcher reports it

[a] Bull. 39, N. Y. State Mus., 1900.

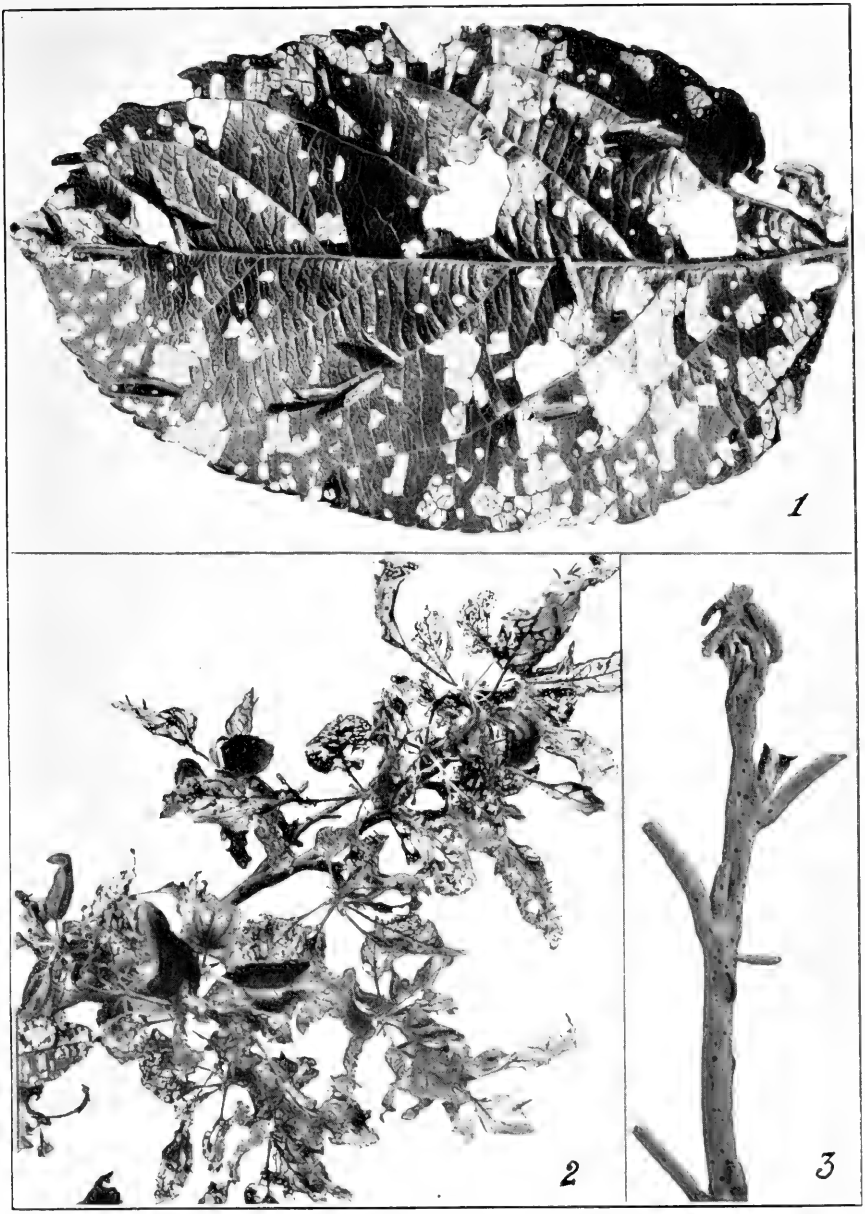
[b] Bull. 34, n. s., Div. Ent., U. S. Dept. Agr., p. 38.

from Ontario, Quebec, Nova Scotia, Prince Edward Island, and British Columbia. In the State of New York it has been recorded by Lintner, Slingerland, and others; at Manhattan, Kans., by Faville; at Santa Fe, N. Mex., by Cockerell; at North East, Pa., by the writer; at Port Hope, Mich., by Pettit, and at Douglas, Mich., by Braucher.

FOOD PLANTS AND INJURY.

The insect has a rather limited list of food plants. Originally it probably fed on native crab apples and certain species of Cratægus. With the extensive planting of orchards, it has found in apple and pear favorite food plants, and it is largely to these two fruits that its depredations have been confined. It has also been recorded feeding upon quince and plums, and will undoubtedly be found on other trees allied to them.

Like many other injurious insects, the work of the cigar case-bearer, when the species is present in destructive numbers, comes suddenly into evidence. The caterpillars infest mainly the leaves, but in the spring they may also be found on the buds and the young fruits. Injury at this time of the season is naturally quite important as affecting both the vigor of the trees and the development of the fruit. As shown in Plate I, figures 1 and 2, the foliage, under conditions of serious infestation, becomes practically skelétonized. In the orchard at North East, Pa., which came under the writer's observation in 1908, the foliage was completely devoured and withered by the early part of June, and from a distance appeared brown and dead, as if swept by fire. Neighboring fruit growers believed this to be due to the burning effect of an arsenical spray, but as a matter of fact the orchard had, to the knowledge of the present owners, never been sprayed. When inspected, June 3, the larvæ, in their cigar-shaped cases, were found in such great numbers that not only had the foliage been completely devoured, but the tender growths of the branches had been very generally attacked. (Pl. I, fig. 3.) It was probably owing to lack of food that they were dropping down from the branches, suspended by a silken thread, in search of new feeding places. The owner, Mr. A. L. Short, and his team at the time of plowing the orchard were completely covered with the larvæ and presented a very strange sight. In looking through the spaces between the rows of trees one was impressed with the abundance of the larvæ, for their cases in countless numbers, suspended by silken threads and waving back and forth in the breeze, almost resembled a drapery. As the larvæ ceased feeding by about the middle of June, the trees put out a new growth of leaves, and later in the season the condition of the orchard was favorable to its recuperation from the attack.



THE CIGAR CASE-BEARER (COLEOPHORA FLETCHERELLA).

Fig. 1.—Apple leaf with larvæ at work (enlarged). Fig. 2.—Infested apple twig, two weeks after larvæ ceased feeding (reduced). Fig. 3.—Young branches with puncturelike feeding marks of the larvæ (natural size). (Original.)

DESCRIPTION.

THE EGG.

The minute egg (fig. 10, *d*), which is hardly visible to the naked eye, is pale yellow, and over the surface is closely marked with elevated ridges. On the average, it measures 0.31 by 0.25 mm. and is almost round in outline.

THE LARVA AND ITS CASES.

When newly hatched the larva is pale yellow, with the head and thoracic plates dark brown or nearly black. The full-grown larva (fig. 10, *c*) averages 5 mm. to 5.3 mm. in length and 1.16 mm. in greatest width. Its head is 0.5 mm. wide and is dark and strongly chitinized, with the ventral surface lighter than the rest. The body is reddish orange, with dark plates as follows: The cervical plate on the prothorax, subdivided by a white interspace; two smaller plates on the dorsum of the mesothorax; a pair of lateral plates on each thoracic segment; a large anal plate on the terminal segment; a small plate on the side of each anal leg. The crochets on the fourth pair of abdominal legs are absent, and on the first three pairs are rudimentary or wanting, varying from none to 4, in one or two rows. The anal legs have from 10 to 13 well-developed crochets placed in a single row. The spiracles are round and feebly indicated. The thoracic legs are large, dark brown, strongly chitinized, and with a chitinous plate behind the basal portion of each leg. The setæ on the head, thoracic legs, and terminal portion of the body are distinct; on the abdominal segments they are rather indistinct. The abdominal segments are distinctly divided into two annulets, and the dorsal surface of each annulet is minutely granular.

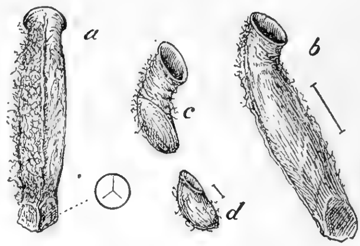


FIG. 9.—The cases of the cigar case-bearer (*Coleophora fletcherella*): *a*, Upper view of the cigar-shaped case, showing the smooth and the hairy sides and the three-lobed hind opening; *b*, side view of same; *c*, the case as it appears in the spring, with the tubelike addition; *d*, the fall and winter case. Much enlarged. (Original.)

The case, as it is made in the fall, is a minute, flattened structure (fig. 9, *d*) composed of portions of the upper and lower skins of the leaf. In the spring, with the growth of the larvæ, the anterior opening is prolonged into a tube made from fragments of leaves fastened by silk (fig. 9, *c*). The second case, in which the larva finally pupates (fig. 9, *a*, *b*), is longer, cylindrical or cigar-shaped, slightly compressed laterally, and with a more or less distinct ridge above and beneath. The anterior opening is round, slightly funnel-shaped, and bent downward, so that the plane of the opening forms an acute angle with the longitudinal axis of the case. The posterior end terminates in three lobes, which neatly close the opening. The average length of the cigar-shaped cases is 6.5 mm. and the width 1.3 mm. They are of a light brownish color, much like that of the dry leaves. As the case is made from the skin of the upper and lower sides of the leaves, the one side is hairy or velvetlike, while the opposite side is almost smooth.

THE PUPA.

The pupa (fig. 10, *b*) has an average length of from 4 to 5 mm. It is light brown, long and slender, terminating posteriorly in a broad, somewhat depressed cremaster, with two short lateral spines on either side; the wing sheaths are narrow, with free, pointed extremities reaching almost to the end of the body; the hind borders of the abdominal segments are smooth; there is a chitinous semiringlike ridge on the anterior portion of the third to seventh abdominal segments. On emergence of the adult, the pupal skin remains within the case.

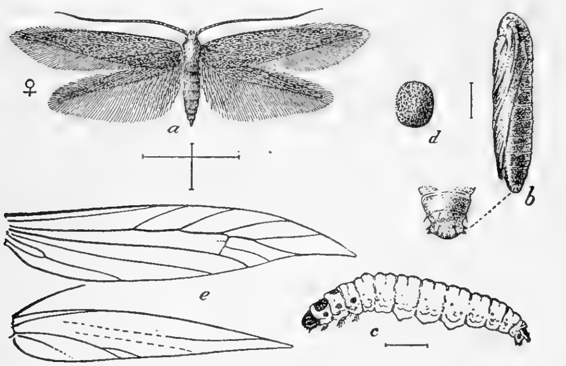


FIG. 10.—The cigar case-bearer (*Coleophora fletcherella*): *a*, Adult female; *b*, side view of pupa and upper view of cremaster of same; *c*, larva; *d*, egg; *e*, venation of fore and hind wings. Much enlarged. (Original.)

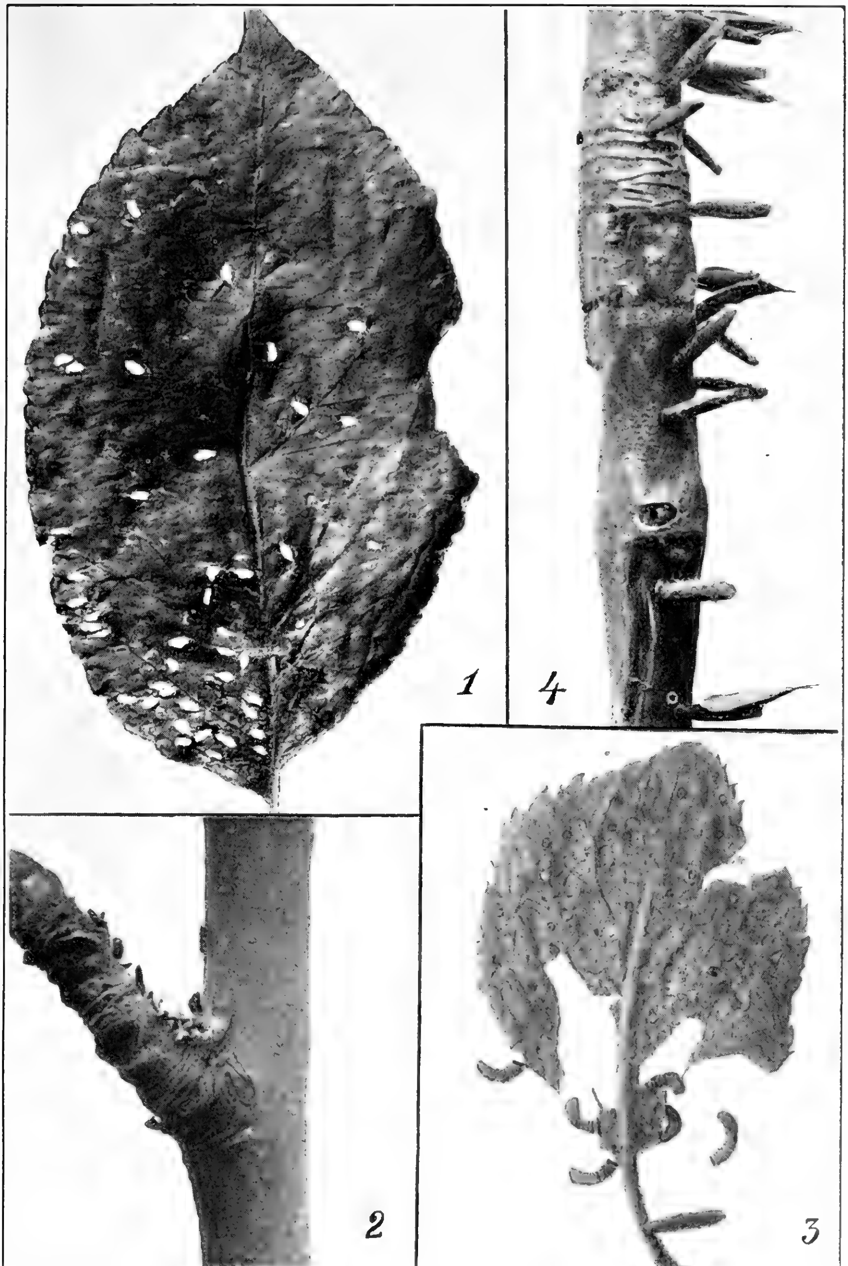
THE MOTH OR ADULT.

The original description of the moth (fig. 10, *a*, *e*), as published by Fernald,[a] is herewith given:

Expanse of wings from 10 to 12 mm. Head, palpi and basal joint of the antennæ, yellowish steel gray. Body, legs and wings above and beneath, plain steel gray, much more intense in fresh specimens. The palpi are without tufts, the basal joint of the antennæ with a slight tuft, and the remaining joints of the antennæ and also the joints of the tarsi are steel gray annulated with white.

The two sexes are similar in color, the male, however, being smaller and recognizable by the blunt termination of the abdomen. The abdomen of the female is larger, more or less spindle-shaped, and terminates in a slender ovipositor, which as a rule protrudes from the last segment. The wings are typically like those of the Tineidæ; narrow, pointed, with the veins in the hind-wings almost obliterated; the hind border of both wings is fringed with long hairs, which are especially pronounced in the hind-wings. On emerging from the pupa the moth assumes a very characteristic pose, as illustrated in Plate II, figure 4.

[a] Can. Ent., 1892, p. 122.



THE CIGAR CASE-BEARER.

Fig. 1.—Apple leaf from which numerous cases have been constructed. Fig. 2.—Overwintering larvæ (enlarged). Fig. 3.—Apple leaf from which cigar-shaped cases have been made, the empty spring cases still adhering (enlarged). Fig. 4.—Newly emerged moths in their characteristic pose on the empty cases. (Original.)

SEASONAL HISTORY.

In the early spring, as the buds begin to open, the minute larvæ free their cases (fig. 9, *d*) from the branches where they have over-wintered, and begin to move about in search of food. Many of them reach the buds before these are opened, and eat into the soft inner tissues. By the time the leaves have begun to expand practically all of them have left their hibernating places and are actively feeding upon the delicate leaves.

With the growth of the larvæ an addition is built to the case in the form of a tube. This extends from the anterior opening on the lower side of the case, and consists of fragments of leaves and silk. (See fig. 9, *c*.)

Fletcher observed that occasionally a larva, on reviving in the spring, would leave its old case and make a new one, but as a rule the old case is detached from its winter resting place and is used for some time before a new one is made.

Toward the middle of May the larva makes a case of an entirely different appearance. After having undermined a sufficiently large area on the leaf, the larva abandons the old case, which usually remains attached to the leaf (Pl. II, fig. 3) and from the upper and lower skins of the leaf cuts out the future case. At first this is of an elongated, somewhat flattened shape, but as it becomes lined inside with silk it assumes a more cylindrical or cigar-shaped form. On close observation it will be found that one side of the case is of a hairy or woolly structure, while the opposite side is smooth. This is readily explained by the fact that the case is made from the upper and lower epidermis of the leaf, the lower surface being hairy and the upper practically smooth. In this case the larva will continue feeding for about one month. During that period it grows rapidly and consumes a relatively large amount of food. The injury caused at this time, though very extensive, is perhaps not more serious than in the early spring, when the opening buds are mutilated or killed by young larvæ.

For some unknown reason it sometimes happens that a larva with a cigar-shaped case will abandon it and make a new one which is apparently similar in all respects to the one previously used. The writer has also observed larvæ transforming in the spring cases. This is probably owing to a lack of food, since these specimens, as a rule, seldom attained their full size. About the middle of June the larvæ cease feeding and migrate from the leaves to the branches. The anterior end of the case is firmly fastened to the branch by means of silk, and a mass of silk is placed in the same end for the attachment of the cremaster of the future pupa. The larva turns around within the case before transforming, so that the head of the pupa is toward the posterior and free end of the case. The opening at this end is closed by three lobes, which are readily pushed apart by the emerging adult. A day or two after the fastening of the case, pupation takes place, and from ten to twelve days later the adult emerges.

At North East, Pa., the first adult emerged June 22; the maximum emergence took place during the early part of July, while after July 25 no adults emerged. As a rule, the adults emerge in the afternoon, and for several hours remain motionless on the case in a characteristic pose, as shown in figure 4 of Plate II. Toward evening they become restless and fly off. Moths even a few days old generally seek their favorite resting place on the attached cases.

The eggs are generally laid along the midrib, on the underside of the leaves, where they are found inserted in the pubescence or down of the leaf. A few eggs were similarly found on the hairy branches. The egg period lasts from fifteen to sixteen days.

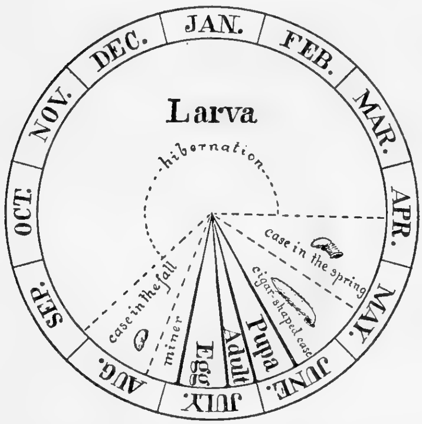


FIG. 11.—Life cycle of the cigar case-bearer: Adapted to a single insect under average normal conditons. (Original.)

The newly hatched larvæ are quite active, and were found moving about for several hours before eating their way into the leaves. During their early life they are true miners and feed for about two weeks on the inner tissues of the leaves. Their mines take the form of minute, elliptical, brown patches, and are readily located by the presence of the black powdery excrement which the larvæ eject from the mines.

Toward the beginning of August the larvæ construct a minute case from the upper and lower skins of the mined area of the leaf. Plate II, figure 1, shows a single leaf from which numerous cases of this kind have been made.

Before the foliage is ready to drop, the minute case-bearers migrate to the branches, where they fasten their cases and seal themselves up for the winter. During the latter part of August and early September they were found in great numbers, especially in the forks and to some extent on the lower side of the branches. (See Pl. II, fig. 2.) For seven months the larvæ remain thus concealed in a dormant state, and, as previously stated, do not become active until spring.

A general idea of the life cycle of the insect may be obtained from the diagram, figure 11. It shows the life cycle of a single insect, the dates and periods shown being averages for the insect as it was observed in its various stages in the field.

ENEMIES.

PARASITES.

Fletcher in 1897 reported a hymenopterous parasite of this insect, *Microdus laticinctus* Ashm., from Port Hope, Ontario.

At North East, Pa., at the time of the emerging of the adults, another hymenopterous parasite, *Habrocytus* sp. (fig. 12), as determined by Mr. J. C. Crawford, was reared in considerable numbers. About 10 per cent of the transforming insects were parasitized.

PREDACEOUS ENEMIES.

The writer found that the eggs of the case-bearer were extensively destroyed by a minute yellow mite, which during the egg period was very abundant all over the orchard. The larvæ of the lacewing fly (*Chrysopa oculata* Say) and various species of ladybird beetles vigorously attacked the eggs and larvæ.

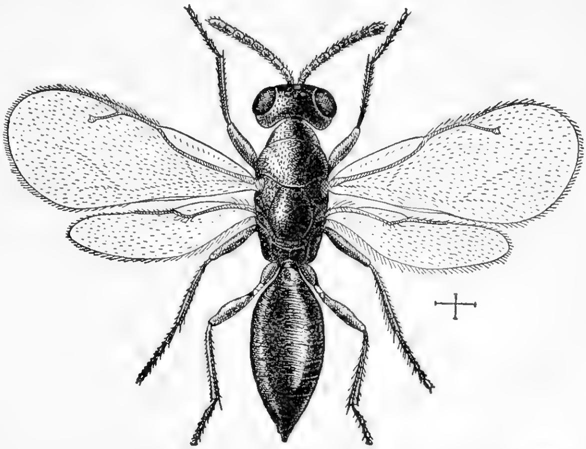


Fig. 12.—*Habrocytus* sp., a parasite of the cigar case-bearer. Greatly enlarged. (Original.)

METHODS OF CONTROL.

A full account of the results of the various spraying experiments carried out in Canada by different fruit growers will be found in Fletcher's report for 1894 as entomologist and botanist for the Canadian experimental farms, pages 201 to 206. It was well demonstrated that the insect can be held under control with either a kerosene emulsion or a Paris green spray applied in the early spring before and while the leaf buds are opening.

In orchards regularly treated with arsenical sprays for the codling moth the cigar case-bearer, if present in orchards, will undoubtedly be kept in check.

BIBLIOGRAPHY.

1889. Lintner, J. A.—*Coleophora* sp.<5th Rep. Ins. N. Y., p. 324.

1890. Lintner, J. A.—*Coleophora* sp. A new pear insect.<Proc. Western N. Y. Hort. Soc., pp. 22–24.

First account of the insect's life history; refers to injury and recommends an arsenical spray.

Lintner, J. A.—*Coleophora* sp. A new pear insect.<Popular Gardening, Buffalo, N. Y., 1890, p. 198.

Same as previous account.

1891. Lintner, J. A.—*Coleophora* sp. A new pear insect.<7th Rep. Ins. N. Y., pp. 347, 361.

Same as above.

1892. Fernald, C. H.—*Coleophora fletcherella*, n. sp.<Can. Ent., vol. 24, pp. 122–123.

Original description of the species.

Fletcher, J.—*Coleophora* sp.<Evidence of the Entomologist and Botanist before the House of Commons, p. 9.

Brief account of its life history and results from spraying.

Fletcher, J.—*Coleophora* n. sp. The cigar case-bearer of the apple.<Exp. Farms [Canada], Rep. Ent. and Bot. for 1891, pp. 196–198.

Further accounts of spraying experiments.

1893. Fletcher, J.—*Coleophora fletcherella* Fernald.<Exp. Farms [Canada], Rep. Ent and Bot. for 1892, p. 4.

Brief mention.

Lintner, J. A.—*Coleophora* sp. on apple leaves.<8th Rep. Ins. N. Y. for 1891, pp. 264, 297.

Lintner, J. A.—*Coleophora* sp.<9th Rep. Ins. N. Y., p. 374.

Brief mention.

1894. Fletcher, J.—*Coleophora fletcherella* Fernald.<Evidence of the Entomologist and Botanist before the House of Commons, p. 19.

Brief mention.

Fletcher, J.—Injurious insects of the year 1894.<25th Ann. Rep. Ent. Soc. Ont., pp. 79–80.

Short account of the life of *C. fletcherella* and its control.

Fletcher, J.—The cigar case-bearer.<Can. Hort., vol. 17, p. 302.

Inquiry about the cigar case-bearer, with reply by Fletcher.

1895. Fletcher, J.—*Coleophora fletcherella* Fernald. The cigar case-bearer of the apple.<Exp. Farms [Canada], Rep. Ent. and Bot. for 1894, pp. 201–206.

Extensive account of spraying experiments.

Bailey, L. H.—The recent apple failures of western New York.<Cornell Exp. Sta. Bull. 84.

Slingerland, M. V.—The cigar case-bearer.<Bull. 93, Cornell Agr. Exp. Sta.

An extensive and good account of the insect, illustrated with photographic reproductions.

1895. WEBSTER, F. M.—Ohio Farmer, June 27, 1895, p. 503, 3 figs.

A summarized account of the cigar case-bearer with special reference to Cornell Experiment Station Bulletin 93.

1896. COCKERELL, T. D. A.—*Coleophora fletcherella* Fernald.<Bull. 19, N. Mex. Agr. Exp. Sta., p. 117.

Introduced into New Mexico on infested nursery stock from New York State.

FLETCHER, J.—Insect injuries of the year 1895.<26th Ann. Rep. Ent. Soc. Ont., p. 37.

Mention of *C. fletcherella* Fernald.

FLETCHER, J.—The cigar case-bearer of the apple.<Can. Ent., vol. 28, No. 5, pp. 128–130.

A brief account of the insect; reference to Slingerland's work.

FLETCHER, J.—The cigar case-bearer (*Coleophora fletcherella* Fernald). <Exp. Farms [Canada], Rep. Ent. and Bot. for 1895, pp. 153–155.

Further spraying experiments.

1897. FLETCHER, J.—The cigar case-bearer (*C. fletcherella* Fernald).<Exp. Farms [Canada], Rep. Ent. and Bot. for 1896, p. 252.

A brief note of results of kerosene emulsion spray.

FLETCHER, J.—*Coleophora fletcherella* Fernald.<27th Ann. Rep. Ent. Soc. Ont., p. 67.

Parasite: *Microdus laticinctus* Ashm.

BETHUNE, C. J. S.—Notes on insects of the year 1896.<27th Ann. Rep. Ent. Soc. Ont., p. 57.

Mention of *C. fletcherella* Fernald.

LOWE, V. H.—Inspection of nurseries and treatment of infested nursery stock.<Bull. 136, N. Y. Agr. Exp. Sta., Geneva.

Mention of *C. fletcherella* Fernald.

1898. FAVILLE, E. E.—The cigar case-bearer.<The Industrialist, April, 1898, pp. 271–275, 7 figs.

An account of its occurrence at Manhattan, Kans., life history, mode of control.

1899. BEACH, S. A., V. H. LOWE, F. C. STEWART.—Common diseases and injurious insects to fruits.<Bull. 170, N. Y. Agr. Exp. Sta., Geneva, pp. 381–445.

Brief description of *C. fletcherella* and life history.

1900. FORBES, S. A.—The cigar case-bearer.<21st Rep. State Ent. Ill., p. 146.

Not *C. fletcherella* Fernald, as reported.

FELT, E. P.—Illustrated descriptive catalogue of some of the more injurious and beneficial insects.<Bull. 37, N. Y. State Mus., Vol. VIII, pp. 8–9.

Brief note on *C. fletcherella* Fernald.

1901. FELT, E. P.—The cigar case-bearer.<Country Gentleman, November 7, p. 902.

Brief account of the insect.

FLETCHER, J.—*Coleophora fletcherella* Fernald.<Bull. 37, Cent. Exp. Farm, Ottawa, Can., p. 72.

Brief mention.

1902. BANKS, N.—Principal insects liable to be distributed on nursery stock.<Bull. 34, n. s., Div. Ent., U. S. Dept. Agr., p. 38.

Brief mention.

1903. LOCHHEAD, W.—A key to orchard insects.<33d Ann. Rep. Ent. Soc. Ont., pp. 104, 105, 108.

Brief mention of *C. fletcherella* Fernald.

1904. BALKWILL, J. A.—Report on insects of the year.<34th Ann. Rep. Ent. Soc. Ont., p. 20.

Brief mention of *C. fletcherella* Fernald.

PETTIT, R. H.—Insects injurious to fruits in Michigan.<Spec. Bull. 27. Mich. Agr. Exp. Sta.

Brief note on *C. fletcherella* Fernald.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

ADDITIONAL OBSERVATIONS ON THE LESSER APPLE WORM.

(*Enarmonia prunivora* Walsh.)

By S. W. Foster and P. R. Jones,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

The prevalence of the lesser apple worm throughout the apple-growing districts of the United States east of the Rocky Mountains, as was pointed out by this Bureau in 1908, has awakened considerable interest among apple growers and others, and as the insect has become better known its importance as a pest is more fully realized. Especially noticeable is the late fall injury caused by the later broods, some of the larvæ of which work in the fruit for weeks after the crop is harvested.

The principal purpose of the present paper is to record additional information on the life history and habits [a] of the insect, and to give a description of the egg, which was first observed during the summer of 1908, both at Siloam Springs, Ark., and in the insectary of the Bureau of Entomology, at Washington, D. C.

It is also desirable to separate, in so far as possible, the injurious work of the lesser apple worm from that of a larva of another species which closely resembles it, and which latter feeds on the twigs as well as the fruit at certain seasons of the year.

All life-history studies were made under normal out-of-door conditions. The senior author, with the cooperation of Mr. E. L. Jenne, made the observations at Siloam Springs, Ark., and the junior author, who also furnished the description and photomicrograph of the egg, conducted the observations at Washington.

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[a] The history, distribution, and character of injury of this species have been fully given by Mr. A. L. Quaintance in Bul. 68, Part V, of this Bureau, and reference to these points will be omitted here.

TWO APPLE CATERPILLARS OTHER THAN THE CODLING MOTH.

Early in the season of 1908 it was noticed that another small larva, the adults of which emerged from June 15 to 25, resembling very closely that of *Enarmonia prunivora*, was feeding in the apples and plums around Siloam Springs, Ark. Later in the season, July and August, adults were reared in numbers from larvæ found in young vigorous growing shoots and water sprouts of apple trees. Most of the injury to the twigs, however, was done in June and July.

The many observations by the writers would indicate that a large part of the first-brood larvæ matures in the fruit; that the remainder of the first brood and also the second brood mature in the young twigs and water sprouts; and that the larger part of the later brood goes back again to the fruit. Adults were secured from fruit from June 5 to 20. After June 23 no more specimens were reared from fruit until August 17, while during this period many adults were reared from the twigs. After August 10 to 15 there was a marked decrease in the twig injury and an increase in fruit infestation. Beginning August 17, many adults were reared from apples throughout the remainder of the season. Adults of this species were determined by Mr. August Busck as *Epinotia pyricolana* Murtf., and its injuries to fruit have not apparently been heretofore recorded. This species has been treated by Prof. E. D. Sanderson in the Twelfth Report of the Delaware College Agricultural Experiment Station (1900) pages 194–199.

During the season the writers were unable to obtain a single specimen of *Enarmonia prunivora* from twigs of the apple, but all specimens taken proved to belong to *Epinotia pyricolana*. In the Ozark region and also in the vicinity of Washington, D. C., this species is far less abundant than either the codling moth or the lesser apple worm.

COMPARATIVE ABUNDANCE OF THE LESSER APPLE WORM AND THE CODLING MOTH IN APPLES.

The injury caused by the lesser apple worm early in the season is not so pronounced, nor are the larvæ so abundant as those of the codling moth, but by midsummer and fall there is a marked increase in the number of larvæ of this species over that of the codling moth. This increase is often sufficient to bring the total number of lesser apple worms, in the fruit for the season, in excess of the codling-moth larvæ.

Records were kept of the comparative abundance of the two species by bringing in during the season infested fruit from unsprayed orchards and keeping the infested fruit collected on different dates in separate breeding cages. Each lot was examined daily for full-grown larvæ and adults.

Table I gives the relative number of the two species as obtained from wormy apples picked from the trees, each picking including some windfalls, which would tend to slightly increase the percentage of Enarmonia larvæ.

TABLE I.—*Relative seasonal increase of Enarmonia prunivora over codling moth larvæ in windfalls and in fruit picked from trees in orchard of D. S. Ballou, Siloam Springs, Ark., 1908.*

Quantity of apples.	Date collected.	Number specimens of Enarmonia and Epinotia.[a]	Number specimens of codling moth.	Percentage Enarmonia and Epinotia larvæ.[a]
1 gallon	May 14	4	6	40
½ gallon	May 26	11	25	30.5
2 gallons	June 8	21	61	25.6
2½ gallons	June 30	15	22	40.5
3 gallons	July 16	84	24	77.8
3 gallons	Aug. 4	120	53	59.3
4 gallons	Aug. 22	62	17	78.5

[a] Enarmonia and Epinotia larvæ were not separated in Tables I and II, as it was not possible to readily distinguish between them. However, there were very few specimens of Epinotia till late in the season, i. e., after the middle of August, and then in small numbers as compared with the number of Enarmonia.

Table II, prepared by Mr. E. L. Jenne, is from wormy fruit picked from trees at intervals stated, no windfalls being included.

TABLE II.—*Relative seasonal increase of Enarmonia prunivora over the codling moth in fruit picked from trees, Flickenger orchard, Siloam Springs, Ark., 1908.*

Number of apples.	Date collected.	Number specimens Enarmonia and Epinotia.[a]	Number specimens of codling moth.	Percentage Enarmonia and Epinotia larvæ.[a]
139	May 26–7	6	80	7.0
56	June 20	10	28	26.3
58	June 30	17	22	43.6
64	July 16	17	27	38.6
156	July 31	44	77	36.4
129	Aug. 16	95	54	63.8
107	Sept. 1	95	39	70.9

[a] See footnote to Table I.

SEASONAL HISTORY AND HABITS.

Information regarding the overwintering or hibernating habits of the larva of this insect is not yet complete. Overwintering larvæ have been found in cracks and crevices of the bark of trees, and also in fruit and barrels which had been stored over winter. Searching through the rubbish around the apple bin of a vinegar factory on March 24, Mr. E. L. Jenne and the writer found larvæ of Enarmonia at the rate of 4 to 135 larvæ and pupæ of the codling moth. A few days later 234 larvæ and pupæ of the codling moth located from 3 to 8 feet above ground were collected from the framework of the same apple bin. No larvæ or pupæ of Enarmonia were found. Larvæ have been found in great abundance in late fall in the partly devoured fruit of Cratægus, both on the trees and on the ground. Many larvæ passed the winter in this fruit in our breeding jars, and this overwintering habit very probably obtains under natural conditions. (See Pl. III, fig. 2.)

From many observations on larvæ in fruit during the winter months, the difficulty of rearing moths in spring from overwintering material and the very light infestation of orchards by the first-brood larvæ point to a high mortality among the larvæ during the winter.

Moths from overwintering larvæ of Enarmonia emerge about the same time as those of the codling moth. At Washington, D. C., moths emerged in 1908 from April 26 to 28 and during the first few days of May from quantities of Cratægus berries which had been kept out of doors in jars and cages over winter. Mr. Jenne secured adults April 18 to 30, 1909, from overwintering larvæ at Siloam Springs, Ark. Other moths emerged May 1, 7, and 9, 1909.

At Washington, during the spring of 1909, moths emerged from the fruit of Cratægus maintained under out-of-door conditions as follows: April 6, 1; April 24, 3; April 26, 6; April 29, 3; April 30, 4; May 1, 6; May 3, 6; May 4, 9; May 7, 14; May 10, 29; May 12, 9; May 14, 7; May 17, 1; May 18, 3; May 22, 2; May 25, 3; May 26, 1; and May 28, 1, which was the last individual to appear.

In the Ozark region the first brood of larvæ matures usually during the month of June; moths for the second-brood larvæ emerged in 1908 from June 20 to July 30. Eggs deposited in breeding cages by these moths July 10 to 12 produced full-grown larvæ July 30 to August 10, the adults emerging August 14 to 26. Eggs from these latter gave another brood of full-grown larvæ September 19 to 30. Other adults, emerging later, deposited eggs as late as September 7 to 14, the full-grown larvæ leaving the fruit October 3 to November 6, when observations ceased, some larvæ being still at work in fruit.[a] This is strong evidence of three full generations annually for the Ozark region. Since many moths had emerged from first-brood larvæ before July 10 to 12, when the above individual records began, it is possible that some of the earlier ones emerged in time to give rise to a partial fourth brood of larvæ.

LIFE CYCLE AND DURATION OF STAGES.

THE EGG.

Individual records kept for 120 eggs during July, August, and September gave the minimum time of incubation as four and one-sixth days and the maximum five and one-half days. Most of the eggs

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[a] Moths emerged as late as September 26, but no records were kept of eggs deposited after September 14.

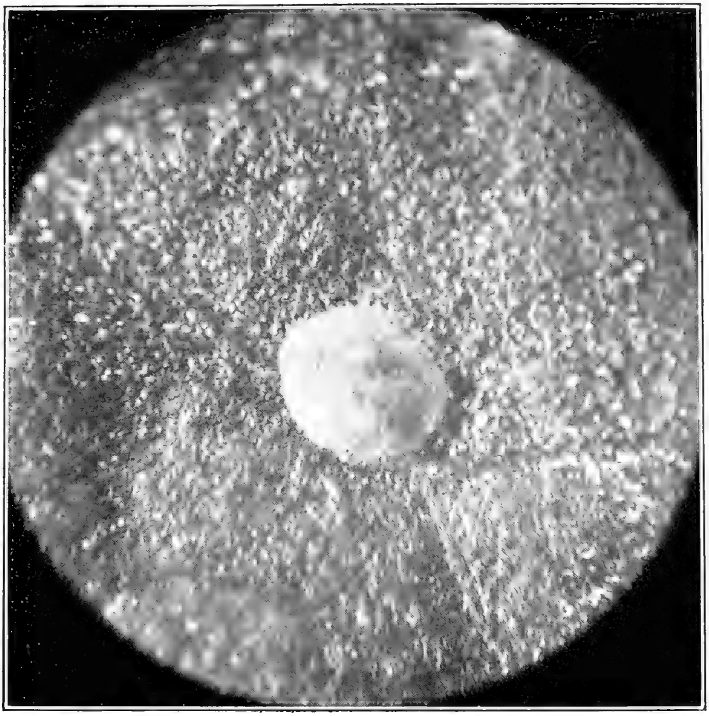

FIG. 1.—PHOTOMICROGRAPH OF EGG OF LESSER APPLE WORM (ENARMONIA PRUNIVORA). (ORIGINAL.)

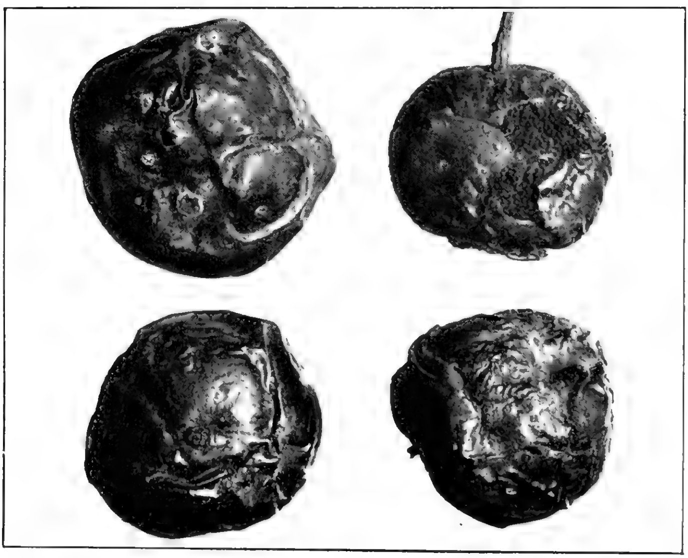

FIG. 2.—WORK OF LESSER APPLE WORM ON FRUIT OF CRATÆGUS. TWICE ENLARGED. (ORIGINAL.)

hatched between one hundred and six and one hundred and twenty-four hours after deposition, the average being slightly more than five days.

The following table of group records taken from batches of eggs deposited on sides of breeding cages and on apple foliage kept inside of cages shows the approximate time of incubation:

TABLE III.—*Period of incubation of eggs of Enarmonia prunivora under normal out-of-door conditions, Siloam Springs, Ark., 1908.*

Number of eggs.	Date deposited, night of—	Black spot appeared.	Egg hatched.	Time.
				Days.
7	Aug. 28	September 2, m	September 3, a. m	$5\frac{1}{4}$
3	Aug. 29	September 3, a. m	September 4, a. m	5
1	Sept. 6	September 11, a. m	September 12, a. m	$5\frac{1}{4}$
5	Sept. 7	September 12, m	September 13, a. m	$5\frac{1}{2}$
11	Sept. 9	September 13, p. m	September 15, a. m	$5\frac{1}{4}$
11	Sept. 11	September 16, a. m	September 16, p. m	$5\frac{1}{4}$
35	Sept. 12	September 17, a. m	September 17, p. m	$4\frac{1}{2}$–$5\frac{1}{4}$
			September 19, a. m	$4\frac{1}{2}$–$5\frac{1}{4}$
4	Sept. 13	September 18, p. m	September 19, a. m	$5\frac{1}{4}$
6	Sept. 14	September 19, p. m	September 20, a. m	$5\frac{1}{4}$

THE LARVA.

The length of the larval period from time of hatching to leaving fruit varied from thirteen to fifteen days during July, from twenty to twenty-seven days in August and the first half of September, and increased to from thirty to fifty days after the middle of September to early November.

Individual records for over 100 larvæ show a minimum of thirteen days and a maximum of fifty days for actual time in fruit of normal healthy larvæ which left fruit prior to November 6.

THE LARVA IN COCOON BEFORE PUPATING.

This period varies greatly, according to where the larva is kept, being much longer when confined with bits of paper, etc., in glasses. From about 100 specimens allowed to spin cocoons in ends of apples, either at the stem or blossom end, the average time during the months of July and August was seven to eight days from leaving the fruit to pupation, the minimum being one day and the maximum twelve days.

THE PUPA.

The actual duration of the pupal stage varies from a minimum of four (?) to a maximum of seventeen days, averaging about ten days. Seventy-four per cent of all pupæ observed in Arkansas developed moths in between eight and twelve days. The records in Washington agree very closely with those in Arkansas.

The total time in the cocoon, from the date of full-grown larvæ leaving the fruit to the emergence of the moths, varies from thirteen to thirty days, although normally it is about seventeen days. Seventy per cent of all moths emerged between thirteen and eighteen days after the larvæ left the fruit.

Taking the normal or average figures for each stage, the complete life cycle requires approximately six weeks, but many individuals complete the life cycle in thirty days in early summer. During the period from August to October some individuals required as high as forty to fifty and a few to sixty days.

DESCRIPTION OF EGG.[a]

Egg: Size, 0.53 to 0.70 mm. long by 0.51 to 0.55 mm. wide; oval in outline, varying to roundish, slightly convex, and covered with a network of irregular ridges. At time of deposition it is pearly white, and resembles very closely in general appearance the egg of the codling moth, except for its smaller size, the ridges being somewhat closer together and not so prominent as with the latter. (See Pl. III, fig. 1.)

The eggs assume a yellowish cast one or two days after deposition, shortly after which a red ring appears; the black head of the larva usually appears in four days.

Moths confined in rearing cages deposited eggs on both sides of the leaves, but mostly on the upper surface on the fruit, stems, and on the glass door and wooden uprights of the rearing cage.

PARASITES.

Only one parasite is recorded in literature from this species, viz, *Mirax grapholithæ* Ashm. During the past season a specimen was reared from a larva infesting apple, which has been determined by Mr. H. L. Viereck as *Phanerotoma*, n. sp.

CONTROL MEASURES.

The usual treatment practiced against the codling moth has so far served to very effectively keep in check serious injury by this species.

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[a] Since this paper was submitted for publication the egg stage has been well described by E. P. Taylor in Journ. Econ. Ent., June, 1909, p. 237.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE PEAR THRIPS AND ITS CONTROL.[a]

(*Euthrips pyri* Daniel.)

By Dudley Moulton,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

Cultivation and spraying, the principal treatments involved in the control of the pear thrips, are largely subject to suitable weather conditions, and each, to be effective, must be accomplished at its proper time. Other orchard work, such as irrigation, cultivation, pruning, and spraying for other insect and fungous troubles, must therefore be considered well beforehand and completed or so arranged that nothing will interfere with the treatment for the thrips. It is highly important that the individual orchardist should have everything in readiness to treat his own orchard at exactly the right time. Preparedness for and thoroughness in the work of spraying and in plowing, it will be found, are the most important factors in the successful control of this insect.

DISTRIBUTION.

The pear thrips is known to occur only in the central part of California, and especially in localities in the general neighborhood of the San Francisco Bay. Reports of its ravages have been received from the Sierra Nevada foothills, near Newcastle and Auburn, and from the

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[a] The control of the pear thrips has been for several years the principal problem confronting the growers of deciduous fruits in portions of central California. This insect, on account of its mode of attack and habits, has presented unusual difficulties in control. It is believed, however, that the investigations of the Bureau of Entomology have now determined practical and efficient measures which, if carefully followed out by orchardists, will insure its reduction below injurious numbers. The investigation has involved a large amount of detailed study of the insects' behavior on the trees and in the ground, and the testing of a large series of spray mixtures, fertilizers, soil fumigants, etc. Mr. Moulton has been continuously engaged in the work for the past three years, assisted a part of the time by Messrs. Charles T. Paine and P. R. Jones. Beginning with the spring of 1909, Mr. S. W. Foster was charged with the operations in Contra Costa County and northward, Mr. Fred Johnson collaborating during the spring months. The present is the second report upon the pear thrips, the first, published as Part I of Bulletin 68 of this Bureau, dealing largely with the insect's life history and habits.—A. L. Quaintance.

Tulare and Fresno fruit districts, but it was found after a careful investigation that none of these fruit areas was infested. In the one case, at Newcastle, the injury was evidently that of the blossom pear-blight and not a single pear thrips could be found in the whole region at a time when the insects should have been in evidence in greatest numbers. A few thrips of another species (*Euthrips occidentalis* Pergande) were found in pear and cherry blossoms in this locality, but this insect is not injurious to fruits, and its presence in blossoms is of no consequence. Thrips from pear blossoms at Visalia were found to be of the species *Euthrips tritici* Fitch, which also is not usually injurious to fruit trees. The present infestation, then, is confined to the region around and closely adjoining the San Francisco Bay. It extends south through the Santa Clara Valley and into Hollister, San Benito County, north through Alameda, Contra Costa, Solano, and Yolo counties, and also occurs in some rather small areas along the Sacramento River. The area of deciduous fruits, about 60,000 acres, in the Santa Clara Valley, is practically all more or less infested by the thrips; and the other infested orchard sections, such as Hollister, Walnut Creek, and Concord, in Contra Costa County, and Suisun and Vaca orchards and others along the Sacramento River, also include many hundreds of acres.

The original home of this species is still in doubt. Several men have expressed the opinion that it is of European origin, but, according to Doctor Buffa, the insect does not occur in Europe, and after examining the species he believes it to be of eastern origin, suggesting China as possibly its original home.

The various thrips which are seen in roses and in other flowers, and which can be found at almost any time of the year, should not be mistaken for the pear thrips, which is distinctly a fruit-tree pest and does not attack grass, weeds, or cultivated flowers. It has, once or twice, been collected from leaf clusters of rose bushes, but this is not common. The name "pear thrips" was given because the insect was first found in pear blossoms, but this does not indicate that it attacks pear trees only. The injury on prunes and other fruit trees is equally as serious as that on pears. Thrips should not be confounded with the vine hopper *Typhlocyba comes* Say, an insect which is wrongly called "thrips," but is not a thrips at all. The term "thrip," so commonly used, is also erroneous, as the word "thrips" is both singular and plural.

CHARACTER OF INJURY.

FEEDING INJURY BY ADULTS.

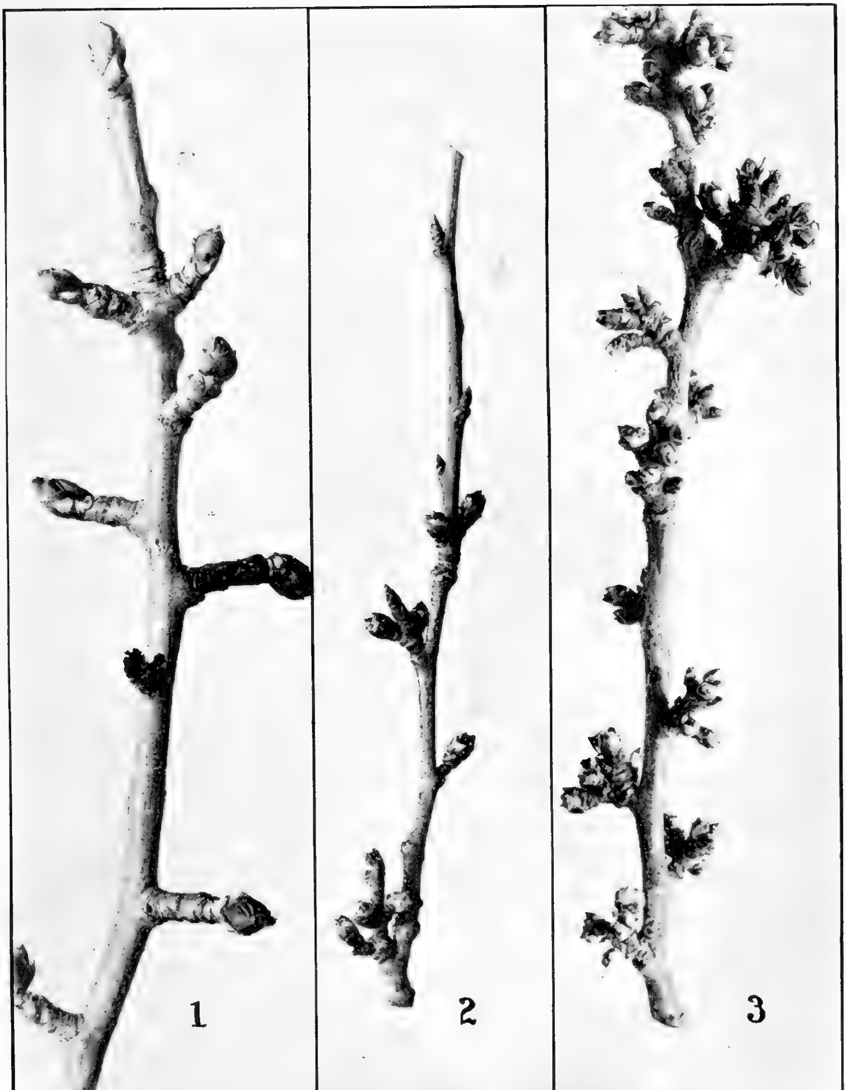
Adult thrips appear on trees during late February and early March, when the buds are just beginning to open (Pl. IV). They remain on the tree until late in April and are thus feeding all through the period of the early opening of buds, of blossoming, and of the unfolding of leaves and the setting of fruit. They come to the trees ravenously hungry after a long fast of ten or eleven months in the ground, and they force an entrance as soon as possible into the first opening buds. Their habit of getting inside immediately has led many orchardists to believe that they in some mysterious way gain entrance into the buds before these are opened. This is not the case, as the insects never enter until after the buds are swollen and partly or wholly opened at the tips. They do not feed on the tough tissues of the bark or on the outer bud scales, but wait until they can get inside. When thrips are very numerous these early buds either never open at all or form only weak blossoms, which present the appearance of having been burned (Pl. V, fig. 1). Thrips will usually migrate in search of new food plants after the blossoms are thus completely destroyed, which explains, in part at least, why they may temporarily disappear from a given orchard or part of an orchard, where perhaps a few days previous they had been numerous enough to destroy the entire crop. When thrips are less numerous the injury is accumulative, but it may finally prove as serious as when many more thrips are present. A few individuals may continue to feed within clusters for days or even weeks. The growth of the tree is then retarded and its blossoms and leaves become weak and deformed. Trees may produce a heavy bloom, even where many thrips are present, but the blossoms and leaf stems will be scarred, weakened, and abnormally short and the fruit does not set. This is especially true of prunes. A few adult individuals may feed in a cluster of pear blossoms, and although the buds drip with exuding sap and are moldy, many if not all of these pears may set and there may follow a heavy crop of fruit, but always in such cases the fruit is ill shaped and badly scabbed. The scabbing on pears (Pl. V) is accomplished almost entirely by adults which feed within the clusters of buds, while scabbing of prunes (Pl. VI) is done almost entirely by larvæ which feed on the fruits under protection of the old calices before these are sloughed off.

Injury by adults in almonds, apricots, and peaches is not serious unless very many individuals are present. These trees bloom rather early, and since each blossom comes singly in a bud, there is offered almost no opportunity for the thrips to get inside until the blossom itself is well opened, whereupon the thrips feed mostly on the nectar glands inside the calyx. This part of the blossom can accommodate quite a few thrips without receiving serious injury, and also the insect is diverted from feeding on the more vital parts. There follows serious injury on these fruits only when many waiting individuals enter the buds and feed on the outside of the little calyx cups and the stems immediately after the winter protecting scales are opened. This group, comprising the almond, apricot, and peach, in which each bud produces but a single blossom, is noticeably less seriously affected by thrips than the group which includes the pear, prune, and cherry, where each bud opens to form a cluster of blossoms. The thrips are admitted into the buds of the latter group immediately upon the spreading of the winter scales and they feed on the outside of the tender blossoms, so that these are weakened before they have a chance to bloom.

Thrips in feeding do not bite off and take internally particles of the outer plant tissue, but tear open the outer layers of plant tissue and, inserting the tips of their mouth-cones, suck up the juices of the plant. This manner of feeding may penetrate through the very young, tender leaves so that later, when the injured parts fall away, the leaves become ragged and full of holes. On very young fruits this feeding injury penetrates through the epidermal layers into the flesh and forms a scab, but on more mature leaves and fruits, where the outer tissues are strong and thick, the effect is that of "silvering."

The relative periods of the spreading of buds and blossoming of the several varieties of fruits are important factors as related to the injury which they receive by adult thrips. Of cherry, the following varieties spread their buds and blossoms in the order named: Republican, Black Bigerreau, Black Tartarian, Royal Ann, and Bingo; and of plum, Japanese plum, and Imperial, Sugar, and French prunes. Such trees as almonds, which blossom very early, or as the Royal Ann cherry, which blossoms late, are not as a rule seriously affected.

The budding and blossoming of fruits in the San Jose district is as follows: Almond buds begin to swell during the latter part of January and early February, and this variety of fruit is in full bloom between February 8 and 24. Apricots show first blossoms from February 19 to 23, and most varieties are in full bloom by from March 3 to 10. Peaches show first blossoms about February 23, and many varieties are in full bloom by from February 8 to March 17. Black Tartarian cherries reach full bloom by March 20, while the Royal Ann variety has not at that time opened its buds. French prune buds are beginning to swell between March 8 and 11 and first blossoms appear by March 20. They are in full bloom from March 26 to April 8. The Sugar and Imperial varieties precede the French by about one week. Bartlett pears begin to open their clusters from about March 12 to 15 and are in full bloom for quite an indefinite period from March 20 to April 10. Pears, prunes, and cherries which are spreading their buds just after the maximum number of thrips are coming from the ground, are the varieties most subject to injury.



CONDITION OF BUDS AT THE TIME WHEN FIRST SPRAYING FOR THE PEAR THRIPS (EUTHRIPS PYRI) SHOULD BE GIVEN.

Fig. 1.—Bartlett pear. Fig. 2.—French prune. Fig. 3.—Imperial prune. (Original.)

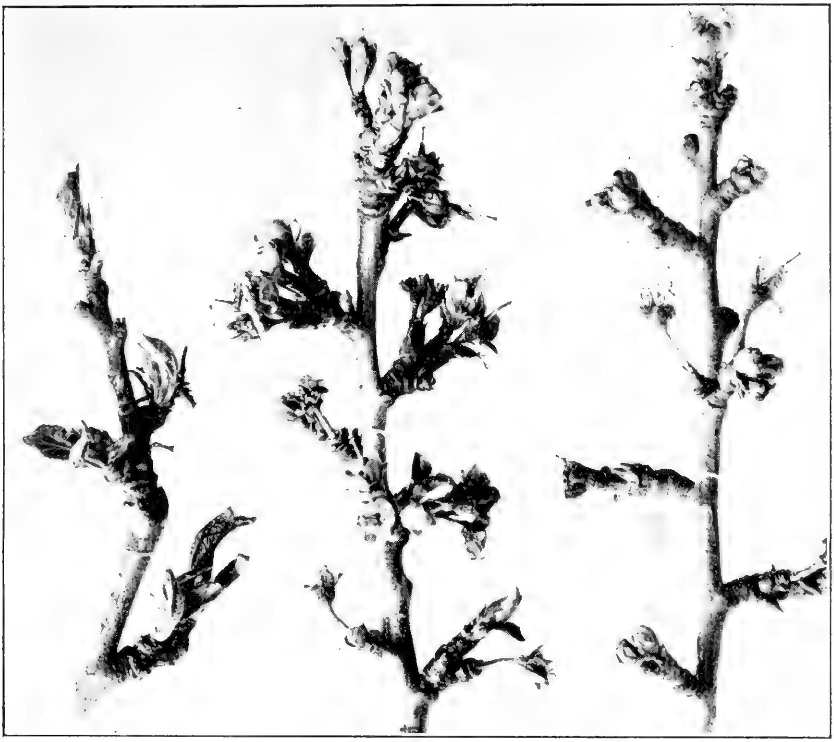
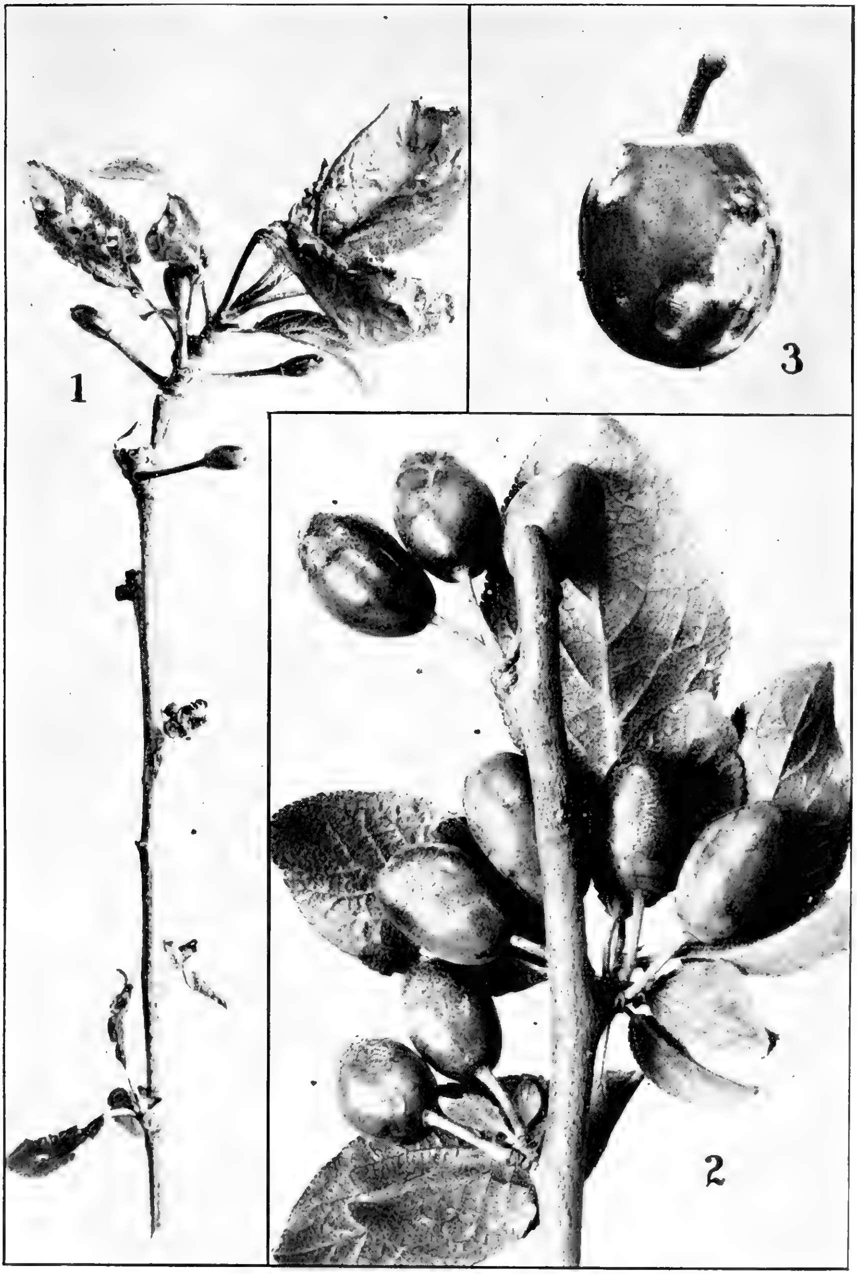


FIG. 1.—DESTRUCTION OF BUDS AND BLOSSOMS. (ORIGINAL.)

FIG. 2.—SCABBING OF FRUIT FROM FEEDING PUNCTURES BY ADULTS ON THE OPENING BUDS IN SPRING. (ORIGINAL.)

WORK OF PEAR THRIPS ON PEAR.



WORK OF THE PEAR THRIPS ON FRENCH PRUNE.

Fig. 1.—Shoot on which crop has been largely destroyed in blossom stage. Fig. 2.—Young fruit, natural size, showing scabbing resulting from work of larvæ. Fig. 3.—Mature fruit showing scabbing injury, resulting in a low grade of dried fruit. (Original.)

The period of blossoming for similar varieties in Contra Costa County is about the same as that in the Santa Clara Valley, while the orchards in the Vaca and Suisun valleys and along the Sacramento River may be a very few days earlier.

INJURY TO TREES BY OVIPOSITION.

The adult female is equipped with a pointed and curved, sawlike ovipositor (fig. 13), by means of which deep cuts are made, into which the eggs are placed well down into the tissues of the plants, mostly in the stems of blossoms or leaves or into the leaf tissue. A single incision is minute and in itself does little harm, as the wound soon heals over, but the tiny stems of the blossoms or of newly setting fruits and the leaf petioles are unfortunately preferred by the insect for ovipositing situations, so that many incisions are often cut into a single stem, which, becoming greatly weakened, turns yellow and the fruit falls. This injury becomes very noticeable at times on the prune and cherry and is undoubtedly the cause of much dropping of immature fruit.

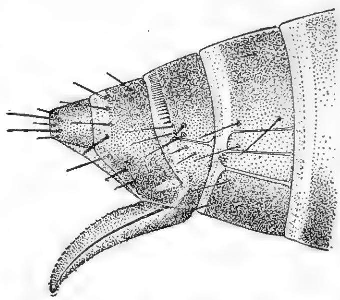


FIG. 13.—The pear thrips (*Euthrips pyri*): Ovipositor and end of abdomen from side. Much enlarged. (Author's illustration.)

INJURY BY LARVÆ.

Thrips larvæ are wingless, never of their own accord traveling from the host plant on which they are born, and usually do not move far from the immediate locality where they have issued from the egg. They seek some sheltered place within a cluster of leaves, in blossoms, or under the protection of the drying calices of such fruits as prunes or cherries. Larvæ are found mostly during the last of March and in April and their injury is distinctly on leaves and fruits and not in opening buds. To them must be attributed almost all the scabbing on prunes (Pl. VI, figs. 2, 3), some silvering on apricots and peaches, and most of the deformed, ragged, and partly dead leaves. This injury to the foliage greatly stunts and weakens a tree if it is repeated during several successive years.

SEASONAL HISTORY AND HABITS.

APPEARANCE OF ADULTS FROM SOIL IN SPRING.

The following table shows clearly just when the first adult thrips are leaving the ground, when in maximum numbers, and when the last individuals are appearing. The figures here represent the total number of thrips collected from four cages from each of four orchards in the Santa Clara Valley, namely, the Landon, Bogen, Sorosis, and Hume orchards. The cages each contained a solid block of earth 17 by 17 inches square, representing a surface area of 2 square feet and a depth of 18 inches, below which thrips have never been found. These cages were removed from under prune and pear trees in the several orchards, brought to the laboratory yard, and again embedded in the ground to their usual depth and covered with a special cage. A daily record was made of the thrips issuing from each cage.

TABLE I.—*Records of emergence from soil of adult pear thrips from four orchards in the Santa Clara Valley, California, spring of 1909.*

Date.	Number of thrips in four cages.				Total.	Date.	Number of thrips in four cages.				Total.
	From Landon orchard.	From Bogen orchard.	From Sorosis orchard.	From Hume orchard.			From Landon orchard.	From Bogen orchard.	From Sorosis orchard.	From Hume orchard.	
1909.						1909.					
Feb. 15	18	0	0	0	18	Mar. 11	13	47	128	310	498
16	0	0	0	0	0	12	12	62	81	183	338
17	51	0	0	1	52	13	18	101	87	207	313
18	176	8	4	4	192	14	1	53	70	124	248
19	160	14	4	14	192	15	3	71	76	129	279
20	126	17	12	14	169	16	1	59	74	125	259
21	60	1	0	14	75	17	3	31	36	72	152
22	84	10	7	18	119	18	1	15	13	13	42
23	106	5	7	17	135	19	8	12	22	19	61
24	403	26	50	73	552	20	1	6	3	18	28
25	301	35	49	74	459	21	0	1	1	0	2
26	320	25	35	64	444	22	2	0	2	2	6
27	232	19	28	134	414	23	0	3	3	7	13
28	372	74	80	255	781	24	0	0	0	3	3
Mar. 1	340	109	114	218	781	25	0	0	0	2	2
2	104	54	92	285	535	26	1	0	1	1	3
3	300	188	258	553	1,299	27	0	0	4	3	7
4	191	104	115	304	714	28	0	0	0	7	7
5	37	93	109	269	508	29	0	0	0	0	0
6	26	34	87	215	362	30	1	1	0	0	2
7	13	50	60	315	438	31	0	0	0	0	0
8	9	38	14	158	219	Apr. 1	0	0	0	3	3
9	18	89	77	602	776	2	0	0	0	0	0
10	18	114	109	256	497	3	0	0	1	0	1

The first adult thrips were collected on February 15, but a very few individuals had been found in blossoms previous to this time. On February 18 they were numerous in one of our experiment orchards, and by February 25 they were common in all orchards. Maximum emergence begins about February 19 and continues until about March 16, a period of three and one-half weeks. A few straggling individuals continued to come out during all the latter part of March and a very few even in April. Practically all thrips, however, are out of the ground by March 20.

The emergence period for thrips in orchards in Contra Costa and Solano counties seems to be three or four days earlier and this will probably hold true also for orchards along the Sacramento River.

MIGRATION OF ADULTS.

The migration of adult thrips is as yet only imperfectly understood. They have wings and are free to fly if they choose, but weather conditions and food supply influence very decidedly their inclination to move about. The tendency is for the thrips to remain quite closely with the trees wherever there are only a few individuals and where the supply of food is abundant. They then fly up during the warm, quiet parts of the day, but do not travel far. It often happens that the insects are so numerous as to kill the early buds or to so injure them that these become brown and dried and do not offer suitable food; the thrips then migrate to other less affected orchards. This migration often occurs before the period of oviposition begins, in which case no new brood is started to infest such an orchard during the following year. This explains why thrips may injure an orchard during one season and seem to have almost entirely disappeared from it the next. This occurrence has led some orchardists to believe that eventually the thrips may move away permanently or die out. This supposition is not correct, and it will be only a matter of a year or two until these orchards will again be attacked.

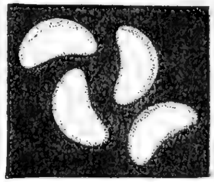


FIG. 14.—The pear thrips: Eggs. Highly magnified. (Author's illustration.)

Migration, then, occurs only during warm, clear weather and is hastened by a desire for better food or for suitable conditions for ovipositing. Thrips locally do not travel in any particular direction, such as south, or east, or west, but distribute themselves generally wherever conditions are favorable for their propagation.

OVIPOSITION.

During the season of 1909 oviposition was not observed until March 10, and by March 15 any number of individuals could be seen placing their eggs. A few larvæ, however, were collected from almond trees on February 26, indicating that earlier eggs had been placed. The period of maximum oviposition begins about March 15, and almost all individuals will be found placing eggs after this date for a period of about four weeks. Ovipositing continues early and late during the day and in all conditions of weather.

THE EGG.

The egg (fig. 14), a white, bean-shaped body, is always embedded in the tender tissue of the stem, leaf, or in small fruits, and is thus protected. After about four days the larva hatches and pushes out through the incision immediately above it.

THE LARVA.

The thrips larva (fig. 15) is white, with red eyes; it moves about slowly and does not jump, and, being without wings, it can not fly. It does not spin a web, but seeks a sheltered place between rolled or folded leaves or in blossoms, or it lies close along the veins on some of the larger leaves. It reaches full growth after two or three weeks, drops to the ground, and penetrates into it for several inches, where it incloses itself in a tiny cell and here remains during all the rest of the year.

Larvæ do not walk down the larger branches or tree trunks to get to the ground, but drop down or are carried within the old falling calices, or are more usually thrown down by winds or rains. It has been observed that a very large percentage of the thrips which are thus thrown from the tree are not fully grown. Only those which are mature are able to penetrate the ground and form their cells; the others die. Larvæ are scattered everywhere under the trees, and if the trees are large and have intermingling branches the thrips are distributed over nearly the whole surface of the soil.

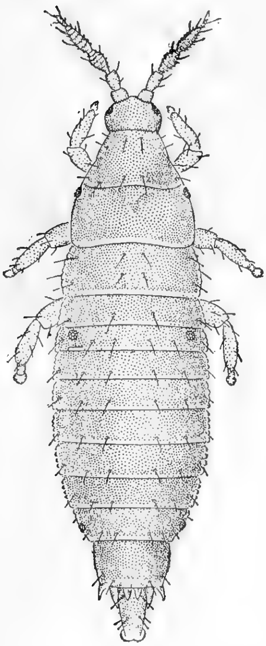


FIG. 15.—The pear thrips: Larva. Much enlarged. (Author's illustration.)

The period during which larvæ are entering the ground begins about April 1, and is at its maximum from about April 10 to 30, practically all thrips having entered by May 15. This period of entering the ground by larvæ in Contra Costa County corresponds very closely to the San Jose record as given above. It may be a few days earlier in the warmer sections at Suisun, in the Vaca Valley, and along the Sacramento River.

Larvæ penetrate the loose top soil and usually remain in the 3 or 4 inches of harder ground immediately below the surface. They penetrate to a much greater depth where the soil is loose, owing to shallow spring cultivation, than where it is firmer. If the thrips are disturbed during their first few weeks in the ground—for example, by cultivation—and if not killed, they immediately go deeper and make new cells. The larvæ remain in a dormant condition, in which no food is taken, and do not move from their cells, unless disturbed, until the fall of the year, when they change to pupæ and their wings begin to develop.

The depth to which these insects penetrate in well-cultivated orchards may be noted in the following tables. In the establishment of these records, blocks of soil 6 by 6 inches square by 20 inches deep were removed from underneath prune and pear trees, brought to the laboratory, and examined in layers, inch by inch, the thrips in each layer being counted. The figures in each case represent the total of all of the samples from each orchard—6 from the Bogen orchard, 10 from the Landon, and 4 each from the Hume and Sorosis orchards. The percentages represent what proportion of the thrips are in the soil above the mentioned depth after which the percentage figures stand. The loose top soil of about 4 inches contained no thrips.

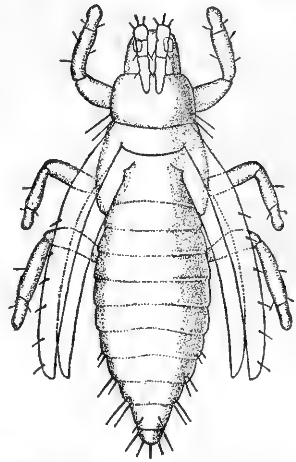


Fig. 16.—The pear thrips: Nymph or pupa. Much enlarged. (Author's illustration.)

Table II.—*Proportion of larvæ of pear thrips in ground at different depths; records from four orchards in the Santa Clara Valley, California.*

No. of layer.	Depth.	Depth of larvæ in soil.							
		Bogen orchard (6 samples).		Landon orchard (10 samples).		Hume orchard (4 samples).		Sorosis orchard (4 samples).	
		No. of thrips.	Per cent.	No. of thrips.	Per cent.	No. of thrips.	Per cent.	No. of thrips.	Per cent.
	Inches.								
5	4 to 5	3	....	249	....	188	....	1	....
6	5 to 6	29	7.75	518	25	277	74	14	12
7	6 to 7	39	17.75	829	54	92	88	55	55
8	7 to 8	45	29	501	71	38	94	25	75
9	8 to 9	71	46.75	305	81	14	95	6	80
10	9 to 10	58	61.25	168	87	7	....	8	....
11	10 to 11	41	71.5	172	....	3	....	9	....
12	11 to 12	26	78	87	....	2	....	6	....
13	12 to 13	25	84	21	....	2	....	1	....
14	13 to 14	17	....	76	....	3	....	0	....
15	14 to 15	12	....	33	....	1	....	1	....
16	15 to 16	4	....	0	....	0	....	0	....
Total number of larvæ.		370	....	2,959	....	627	....	126	....
Average number larvæ per surface sq. foot...		266	....	1,183	....	627	....	126	....

THE PUPA.

The period of pupation begins in September and reaches its maximum during October, November, and December. The insect is at this time forming its new legs, antennæ, and wings, each appendage developing within its own little sac and hanging free at the side of the body (fig. 16). A few prematurely forming pupæ have been collected during midsummer, but it is not probable that these live through the year. They do not mature to form a second brood.

THE ADULT.

Adult thrips (fig. 17) are common in the ground in December and January, but all seem to await the proper time in February before they come out. If they are prematurely broken out from their cells during December or January they are active and can fly, but they never seem to leave the ground at this time of their own accord. The transformation from larva to pupa and to the adult is a slow and gradual one and occupies several months.

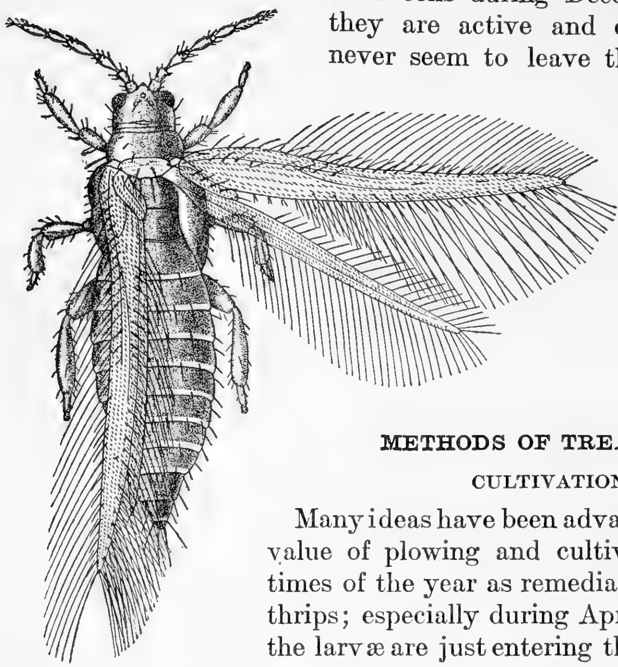


FIG. 17.—The pear thrips: Adult. Much enlarged. (Author's illustration.)

METHODS OF TREATMENT.

CULTIVATION.

Many ideas have been advanced regarding the value of plowing and cultivating at different times of the year as remedial measures against thrips; especially during April and May, when the larvæ are just entering the ground; in May, June, and July, after they are all in; in the fall and early winter, to destroy pupæ; and during February and March, when adults are coming out. It has now been clearly demonstrated that much benefit can be derived in checking the thrips by plowing and otherwise cultivating the ground, if this is done at a proper time and with care.

Thrips larvæ penetrate until they can find a protected place where no light enters. This may be within 2 or 3 inches of the surface, in ground along roadways which is not cultivated and which may be partly covered with grass. They usually rest in the 3 or 4 inches of ground immediately below the loose top soil in regularly cultivated land, and since they are within 8 or 9 inches of the surface, they are thus largely within the reach of the plow. If, from previous improper cultivation, the ground is full of cracks and cavities from decayed weed stems or roots, or is full of wormholes, the larvæ come into these and may then penetrate many inches.

Cultivation during April and May, when the thrips larvæ are entering the ground, will kill a few, but it also disturbs and agitates the others, which then go deeper. Continuous cultivation in June and July, which, however, is not always practicable, would also have the same effect. It should be remembered that these insects are so small that they can easily remain inside of very small clods and be turned over and over again by cultivation without receiving any injury.

The thrips are passing through their pupal development in the late fall and early winter, and they are then more susceptible to mechanical injury than at any other time. They are only slightly active, and can not build other cells if once they are forced from the old ones. Their new legs, antennæ, and wings are sheathed in long, delicate sacs, any one of which may easily be broken or deformed by the least disturbance.

Several experiments with fall and winter plowing for thrips were carried out in the fall of 1908, and the following records show what results have been obtained in two of these orchards, where special attention was given to securing data. Areas of 20 and 70 acres, respectively, were plowed and harrowed, and all of the first, with 20 acres of the second, was cross plowed. This plowing was done mostly during December, a lack of early rains having hindered from doing the work sooner. In each case several samples of soil, 17 by 17 inches square by 20 inches deep, were removed from the orchards, both before and after treatment, brought to the laboratory yard, and embedded to their natural depth in the ground. The cages remained open until a time when the adult thrips began to come out. They were then covered over, and thereafter a daily record of the emerging insects was made for each. The blocks of soil were selected from near-by trees and under like conditions, to insure as far as possible a uniform number of thrips in each.

Cages I, II, III, and IV from the Landon orchard were taken from land which had been plowed and cross plowed in November and December, and cages V and VI, from the same orchard, were taken from under trees where no winter plowing had been done. Cages VII and VIII, from the Hume orchard, were taken from land which was plowed and cross plowed, and cages IX and X from untreated soil.

TABLE III.—*Experiments with fall and winter plowing for the pear thrips in two orchards in the Santa Clara Valley, California.*

LANDON ORCHARD.

	Plowed and cross plowed.				Not treated.	
	Cage I.	Cage II.	Cage III.	Cage IV.	Cage V.	Cage VI.
Total number of thrips	475	389	607	115	1,175	1,474
Total number of thrips per square foot of surface	237	194	303	57	587	734

Average number of thrips per cage:	
Cages I, II, III, and IV	396
Cages V and VI	1,324
Average number of thrips per square foot of surface in each cage:	
Treated	198
Untreated	662
Percentage living in treated areas as against the numbers of thrips in untreated ground	30
Approximate percentage killed	70

TABLE III.—*Experiments with fall and winter plowing for the pear thrips in two orchards in the Santa Clara Valley, California*—Continued.

HUME ORCHARD.

	Plowed and cross plowed.		Not treated.	
	Cage VII.	Cage VIII.	Cage IX.	Cage X.
Total number of thrips	421	643	2,185	1,771
Total number of thrips per square foot of surface	210	321	1,092	885

Average number of thrips per cage:	
Cages VII and VIII	265
Cages IX and X	988
Average number of thrips per square foot of surface in each cage:	
Treated	133
Untreated	494
Percentage living in treated areas as against the numbers of thrips in untreated ground	27
Approximate percentage killed	73

Bearing in mind that the larvæ penetrate into the ground quickly after they leave the trees; that they remain usually below the loose top soil, going deeper if disturbed, and also that they are most susceptible to injury in the pupal stage, cultivating and plowing should be so arranged as to take best advantage of their habits, to encourage their locating near the surface, planning at the same time to reach them by late fall and early winter plowing.

The principle of fall plowing is to use a moldboard or disk plow, and by turning the land over to bring the thrips which rest in the lower strata of ground up to the surface. The land should then be thoroughly harrowed or worked over with a disk cultivator. With the present methods of plowing, a strip of 2 feet or more of undisturbed ground is usually left in the tree row. It is necessary also to plow to a less depth close under the trees than in the middle of the rows. The land should therefore be plowed and cross plowed, to insure breaking up all of the ground to a uniform depth, and harrowed after each plowing, to make the treatment thorough.

The Landon orchard was uniformly plowed to a depth of about 9 inches. It will be seen by referring to Table II that 81 per cent of all the thrips were above this depth and were therefore disturbed. Table III shows that there were 70 per cent less live thrips in ground which had been plowed and cultivated than in that which had received no winter treatment. These thrips, about 89 per cent of all which were disturbed, must therefore have been killed by the cultivating.

The Hume orchard was plowed uniformly to a depth of about 7 inches. Table II shows that 88 per cent of the thrips were between the surface and this depth, and Table III shows that about 73 per cent of the total number of thrips in this orchard were killed by cultivation.

Plowing during February and March, when adult thrips are coming out of the ground, is not practicable because of the usually heavy rainfall at this time, and because the ground breaks up into large instead of small clods, for which reason only a few thrips are killed. Then, too, plowing at this time seems to let the thrips out all at once, thus increasing rather than reducing their injury. Several orchards that have been kept under constant observation, which were plowed during February and early March, were very much more seriously injured than orchards of the same variety of fruit immediately adjoining which were not plowed at this time.

The benefits of plowing and cross plowing have been so evident in every one of the several orchards treated that during the spring one could tell almost to a row, by the healthful condition of the trees, where the plowing began and where it ceased.

A careful examination of the soil under prune trees, after plowing had been accomplished, showed that almost no thrips were present until a depth was reached where the plows had not cut. Below this point the usual numbers of thrips were found.

SPRAYING.

Spraying for thrips has proved wonderfully successful wherever proper sprays have been used and the work done with care and thoroughness, while indifferent and careless work or improper sprays are absolutely ineffective. The thrips must first of all be reached. This necessitates high pressure—125 to 180 pounds—and a rather coarse, penetrating spray. It is necessary also that the spray be directed downward into the buds, and not thrown at them from below or from the sides. It should be remembered that spraying is done, not to drive the insects away or to protect the tree from any possible future attack, but to kill those insects which are actually present on the trees. It may not be possible to reach all of the thrips which are concealed in the buds even with most careful spraying, but a very large percentage of them can be killed. Spraying into partly opened buds and blossoms theoretically seems impossible, but is found entirely practicable when a coarse, forceful spray is thrown down directly against the tips. A tower platform should be built over the spray wagon so that the tops of large trees can be properly sprayed.

Almost all of the standard spray formulas have been thoroughly tested, and all except two have been eliminated. The bodies of the thrips, both adults and larvæ, are decidedly oily and strongly resistant to all sprays which do not readily assimilate the oil. For example, the lime-sulphur solution, which is very caustic, may be thrown onto the thrips, and it will merely gather in globules on their bodies and not penetrate to kill them. Both larvæ and adults have been observed to actually float around in the ordinary soap and lime-sulphur sprays with no apparent inconvenience. Dry sprays are also absolutely ineffective. Emulsions of oil combined with crude carbolic acid or crude creosote are extremely penetrating, in reality killing almost every thrips that they touch, even when applied in a very weak form; but these combinations are just as violently injurious to blossoms and leaves as to thrips, consequently they can not be considered. Poisonous sprays are ineffective because the thrips feed from the inner parts of the plant and not from the outer layers, where the poison would be placed.

Black-leaf tobacco extract diluted to proportions of 1 part extract to 50 of water has been very successful, but this spray seems to demand a somewhat heavier and more penetrating liquid than water alone as a carrying agent. The distillate oil emulsion in 6 per cent dilution is almost as deadly as the black-leaf extract, but there will follow some injury from the spray unless conditions are altogether favorable. The oil spray has the advantage of being heavier, of being forced more easily into the buds, and of penetrating the oily coating offered by the thrips. This emulsion, however, reduced to a 1½ or 2 per cent solution, can be applied with safety to all trees, and when combined with black-leaf extract, diluted at the rate of 1 part of extract to 60 or 70 parts of water, furnishes a spray having all the required carrying, penetrating, and killing qualities desired. This is the spray which is now recommended. It can be applied with safety to opening buds, but should not be used on trees in full bloom. Blossom petals are more sensitive to injury from spraying than any other parts of a tree; but, since they soon fall, the damage, although noticeable, is not often serious. This spray can be applied to trees immediately after the blossoms have fallen, and later to the foliage for adults and larvæ.

The first application should properly be made when the thrips are coming from the ground in large numbers and before the cluster buds are too far advanced. (See Pl. IV, showing stage of development of buds when first application should be made.) This period for the San Jose district of California is early in March, but it differs, of course, for the several varieties of fruits, as stated on page 54. Where the thrips are very numerous it may be necessary to immediately follow this first application with a second. Another application can be made immediately after the blossom petals fall, to kill the remaining adults, but more especially to kill the larvæ. The adults should by all means be attacked first. The spraying for larvæ is merely to alleviate the minor injury of scabbing on fruits, and to protect the trees for the following year by killing the larvæ before they get into the ground.

An effort should be made to kill all adults in an orchard before March 15, when practically all thrips are out of the ground and when oviposition begins.

The black-leaf tobacco extract may be purchased from local agents. The distillate oil emulsion can also be purchased from local dealers in spraying supplies, but is prepared after the following formula:

Hot water	gallons..	12
Whale-oil or fish-oil soap	pounds..	30
Distillate oil (28° Baumé)	gallons..	20

The soap is first dissolved in a kettle of boiling water and then removed to the spray tank, where the oil is added. This should be agitated violently and sprayed out under pressure of from 125 to 150 pounds into other barrels. This stock solution contains about 55 per cent of oil, and should be diluted at the rate of about 2 gallons of the emulsion to 48 gallons of water for a 2 per cent oil solution.

The secret of making a thoroughly good stock emulsion lies in having the soap and water boiling hot, in adding the oil to this solution, and under no circumstances in adding the soap and water to the oil, in thorough and violent agitation, and, finally, in passing it through the spray nozzles under high pressure. It has been found by repeated experiments that high pressure is the most important factor, and an emulsion passed once through the pumps and nozzles under pressure of from 150 to 160 pounds can not be improved by repeating this operation.

Fish-oil soap may be made as follows:

Water	gallons..	6
Lye	pounds..	2
Fish oil	gallons..	1½

Place the water in a caldron, add the lye, and then the fish oil, and boil slowly for about two hours. This will make about 40 pounds of soap or about a 5-gallon mixture.

FERTILIZERS.

The numerous fertilizers and soil fumigants tested have proved ineffectual in killing thrips in the ground, even when applied in proportions far beyond what could be used in ordinary practice. It is evident, however, that most orchards need fertilizers to strengthen the buds and to insure a more regular setting of fruit. It has been demonstrated repeatedly with other crops that soil soon deteriorates unless there is a rotation of crops or unless fertilizers are added.

IRRIGATION.

Irrigating for thrips during any time of the year is entirely ineffectual. Their bodies are so strongly resistant to water that while in the ground it is not practicable to submerge them long enough to insure their destruction. Small areas containing thrips have been submerged as long as seventy-two hours, and when examined a few days later all thrips were alive and active.

SUMMARY.

The pear thrips has been found only in localities in the general region of San Francisco Bay. Its presence in other countries is not known.

The adults accomplish their feeding injury by rasping the tissues and sucking out the plant juices in the early buds and blossoms. Larvæ feed more especially on the larger leaves and on fruits. Adults cause the scabbing on pears, while larvæ produce the scabbing on prunes.

Adults emerge from the ground in late February and early March, just when most trees are spreading their buds and opening into bloom. Eggs are placed mostly in the blossom and fruit stems and in leaf petioles. The larvæ hatching therefrom feed for two or three weeks, then drop to the ground, where they form a tiny protecting cell within which they remain during the rest of the year. The pupal changes take place within this cell in the ground during October, November, and December.

To gain complete control of the pear thrips, both plowing and spraying should be adopted as remedial. Land should be plowed as soon as possible after the early rains in October, November, and December, to a depth of from 7 to 10 inches, harrowed or disked, and then cross plowed, the second plowing to be followed also by harrowing. The pupæ are by this means broken from their protecting cells and most of them either injured or killed.

A combination spray of black-leaf tobacco extract in the proportion of 1 part of extract to 60 parts of water and 2 per cent distillate-oil emulsion, or a spray of black-leaf extract alone, should be used against the adults during early March, just when the cluster buds begin to open, and against the larvæ in April, after the blossom petals fall. The thrips must be killed by contact insecticides, and not by internal poisons.

Fertilizers and irrigation do not kill the thrips in the ground. They act against them only indirectly, by placing the soil in better condition for cultivation and by strengthening the trees.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

ON THE NUT-FEEDING HABITS OF THE CODLING MOTH.

By S. W. Foster,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

The codling moth (*Carpocapsa pomonella* L.) has, up to the present time, been considered as a serious enemy only to pome fruits. It has, however, frequently been found in peaches and plums. There are several European records of walnut infestation by this species, but these reports were carefully sifted by Dr. L. O. Howard in 1887[a] and found to lack sufficient evidence to definitely prove that the codling moth ever feeds either upon nuts or oak galls. C. B. Simpson[b] records that Adkin, in 1895 and in 1896, exhibited specimens and gave details as to the rearing of this insect from chestnuts. In March, 1908, at Siloam Springs, Ark., the writer found a full-grown larva of this species with partially made cocoon inside a hickory nut, but as there were no signs of feeding on the kernel it is probable that the larva had gone in only for the purpose of hibernation and as a safe place for pupating.

NOTICE OF WALNUT INFESTATION.

On October 2, 1909, while visiting the ranch of Mr. George Whitman, near Concord, Cal., the owner mentioned to the writer that worms closely resembling the larvæ of the codling moth were doing serious injury to the walnuts on one of his trees. A large tree near a pear-packing shed was closely examined and found to have over 50 per cent of the nuts infested by larvæ of the codling moth. Larvæ in all stages from a few days old to full grown were found. Egg-shells also were found on the outside of the hull of the nuts and on the leaves, indicating that the eggs had been placed by the moth on fruit and foliage promiscuously, as is customary in the case of apple and pear.

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[a] Rept. Commissioner of Agriculture for 1887, pp. 92–94, 1888.

[b] Bul. 41, Bur. Ent., U. S. Dept. Agr., p. 19, 1903.

NATURE OF INJURY.

The larvæ upon hatching soon bore into the fleshy hull covering the walnut proper. Some individual larvæ one-fourth grown were found feeding in this hull, some burrowing around through the fleshy part, and others tunneling back and forth on the inner surface next to the walnut shell, producing many little narrow furrows along this inner surface. The majority of the larvæ, however, go at once into the nut, entering always through the fibrous tissue connecting the halves of the shell at the base or the stem end. The larvæ may bore into the lobes of the kernel or feed on its surface. Some eat over a large portion next to the shell, some follow along the central area, while others may spend all the time near the entrance, eating away a larger portion of the kernel at this place. In any case the entire kernel is rendered rancid and unsuited for human consumption. Plate VII, figure 1, shows characteristic injury to the walnuts and Plate VII, figure 2, a larva at work in the kernel, the latter twice enlarged.

EXTENT OF INFESTATION.

Extended search throughout the central part of Contra Costa County, Cal., showed the infestation to be general, but light, except where trees were near packing sheds, drying grounds, or adjacent to a badly infested pear orchard. Many trees were found in such localities showing from 5 to 25 per cent of the nuts infested. During the winter of 1909–10 small quantities of walnuts were frequently bought in the local markets and twice from stands in San Francisco from which codling moth larvæ were secured and which showed the characteristic injury to the kernel. The writer has also had the same experience with walnuts served on hotel and dining-car tables. Mr. E. J. Hoddy, of the Bureau of Entomology, has frequently, during the past winter, brought in walnuts from various parts of the county showing the injury and presence of these larvæ.

VARIETIES ATTACKED.

All of the soft-shelled French varieties of walnuts are subject to infestation, and in fact any of the soft-shelled sorts having a fibrous tissue connecting the halves of the shell at base. Moths were reared the past season from the Mayette, Concord, Franquette, and Parisienne varieties.

SEASONAL HISTORY OF THE CODLING MOTH ON WALNUTS.

So far all observations indicate that only the later broods of larvæ attack the walnuts. No walnuts could be found showing early injury, that is, before the shell hardened. Assuming that the larval life in walnuts is the same in length as in apples and pears, the earliest date of infestation would be late August or early September. The Bart-

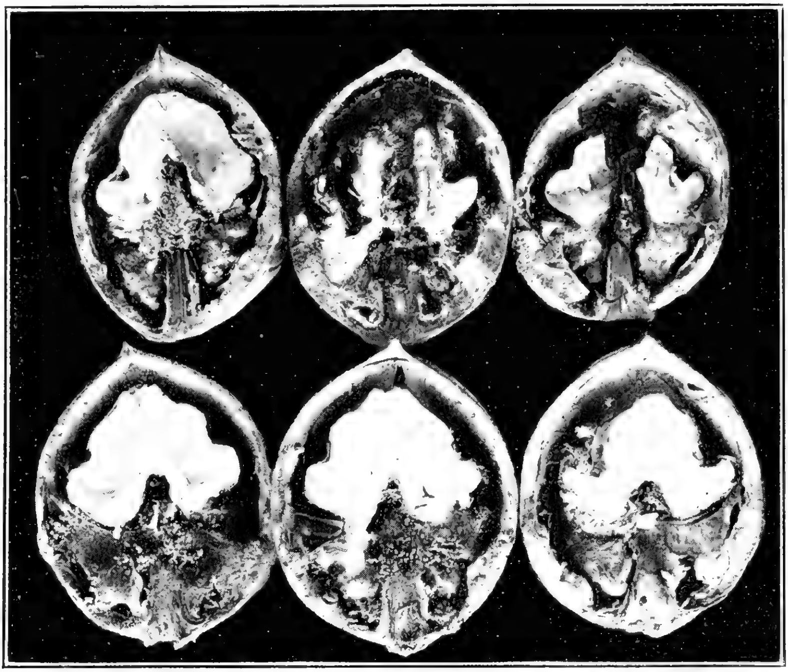

FIG. 1.—CONCORD VARIETY OF FRENCH WALNUT, SHOWING CHARACTER OF INJURY BY LARVÆ OF CODLING MOTH. (ORIGINAL.)

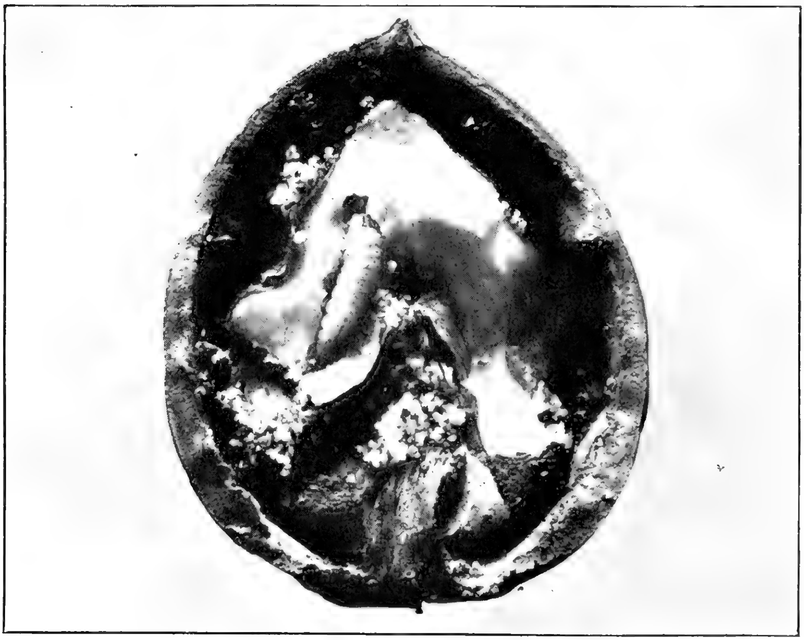

FIG. 2.—CONCORD VARIETY OF FRENCH WALNUT, ABOUT TWICE NATURAL SIZE, SHOWING LARVA AT WORK. (ORIGINAL.)

CODLING MOTH INJURY TO FRENCH WALNUTS.

Fig. 1.—Concord Variety of French Walnut, Showing Fibrous Tissue Connecting the Halves, and Empty Pupal Skin. (Original.)

Fig. 2.—Concord Variety of French Walnut, Showing Entrance and Exit Holes of Larva. (Original.)

CODLING MOTH INJURY TO FRENCH WALNUTS.

lett pear crop around Concord, Cal., is picked prior to this time and before all the second-brood moths have developed. It is entirely probable that these late-appearing individuals seek the walnut as the only remaining plant suitable for oviposition. Thorough search during May and June, 1910, failed to show the presence of any larvæ on trees that were badly infested last season.

Life of larvæ in walnuts.—In spite of the extreme bitterness of the fleshy hull, some larvæ thrive well there for a time before entering the kernel, as several specimens of healthy, active larvæ one-fourth to one-half grown were found in the hull. However, in all cases under observation the larvæ left the hull and entered the kernel before reaching maturity. The majority of the larvæ burrow directly through the fibrous tissue connecting the halves of the shell. Some larvæ are saved the necessity of burrowing through the hull, as this, during the period of infestation, is ripening on many of the early nuts, and on account of the parting of the lobes the small larva has only to eat its way through the thin fibrous connection. No case was noted where the larva entered through the shell.

Time required for development.—No individual records were kept, but all observations show that the larva develops as rapidly on the meat of the walnut as it does in apples at this season of the year. Some larvæ less than a week old, collected in walnuts October 5, reached their full development and were spinning cocoons by the middle of November. Others, however, continued to do more or less feeding on the kernel and did not spin cocoons until January.

Hibernation.—From 1 gallon of infested walnuts kept at the laboratory perhaps one-fourth of the larvæ cocooned and pupated inside the shell. Others, leaving the walnuts at the same place where they entered—that is, through the fibrous tissue connecting the halves of the shell—pupated in bits of paper and rags kept in the jars. Before pupating in the walnuts, the larva prepares an opening through the fibrous tissue sufficient for the exit of the moth and spins its cocoon immediately adjoining this opening. Upon the emergence of the moth the shed pupal skin is left outside on the end of the walnut, as is shown in Plate VIII, figure 1. All larvæ under observation pupated between February 20 and April 10.

Adults.—Moths emerged in numbers from the above material during April and May, 1910, comparing closely with the emergence record of moths from a quantity of overwintering larvæ taken from bands on apple trees the previous season.

Identification.—Numerous adults emerging from this material were submitted to Mr. August Busck, of the Bureau of Entomology, for identification. Mr. Busck has definitely determined these as *Carpocapsa pomonella* L.; he states that the European *Carpocapsa putaminana* Staudinger, recorded as feeding on walnuts in Europe, is now regarded as a variety of *pomonella*.

CONTROL.

As many of the larvæ eat their way through the fleshy hull covering of the walnut, it is probable that a thorough spraying with arsenate of lead in the month of August would greatly reduce the infestation. This treatment would apparently be as effective in destroying larvæ from eggs placed promiscuously over the foliage and nuts as in the case of the apple. From the fact that many of the larvæ gain entrance to the walnut after the hull has parted at the tip, the poison would, of course, not be effective against these. The infestation can, no doubt, be greatly reduced by maintaining the packing shed and drying grounds some distance from the walnut grove.

It is the practice of many pear growers to save all windfalls in the orchard and culls from the packing shed. These pears are either stored in large trays, stacked in the shade, or else the pears are covered with straw in layers on the ground. As a rule, the culls from the packing ground are nearly all infested with immature larvæ of the codling moth, which reach their full development and produce moths during the ripening period of the walnuts. This, in most cases, is the source of infestation of walnut groves found to be most seriously troubled with the codling moth.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIFE HISTORY OF THE CODLING MOTH IN NORTHWESTERN PENNSYLVANIA.

By A. G. Hammar,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

In 1907 the section of deciduous fruit insect investigations of the Bureau of Entomology established at North East, Pa., a temporary field station, for the investigation of certain orchard and vineyard pests. One of these, the codling moth (*Carpocapsa pomonella* L.), has been studied for the three consecutive years of 1907, 1908, and 1909. The rearing work during the first two seasons covered only the more important features in the development of the insect, while in 1909 efforts were made to rear the insect throughout the seasons and to determine the time and relative occurrence of the various stages of the two broods.

In 1907 the work was carried out by Mr. P. R. Jones of this bureau, and in 1908 and 1909 by the writer, who during the last season was assisted by Mr. Edwin Selkregg, of North East, Pa. Mr. Fred Johnson, of this bureau, has for the three seasons contributed to this work numerous field observations. All of these studies have been made under the direction of Mr. A. L. Quaintance, in charge of deciduous fruit insect investigations.

In the presentation of the life-history studies the separate stages of the two generations are first considered in detail as observed in 1909. Later are described certain fluctuations, found in regard to the time of emergence of moths, the time of maturity of larvæ of the two broods, and also a comparison of relative occurrence of larvæ of the two broods for the three seasons under consideration.

The term "brood" is here used in speaking of individuals of one generation of any stage, as egg, larva, or pupa. A generation naturally includes all the stages of the life cycle, and is considered to begin with the egg stage and to terminate with the moth or imago stage of the same generation.

SEASONAL-HISTORY STUDIES OF 1909.

SOURCE OF REARING MATERIAL.

The main portion of the rearing material used in the spring of 1909 was collected during the previous summer and fall from banded apple trees; the rest—a small fraction—constituted reared specimens from experiments of the previous year. The larvæ intended for pupal records were allowed to make their cocoons between narrow strips of wood (fig. 18), where their transformation could be readily observed without greatly altering their conditions, while those for emergence records of the moths cocooned in masses of old bark of apple trees. During the winter the material was kept in a medium-sized glass jar, covered with thin cloth, and was thus left undisturbed in an open shelter (see Plate IX) until the following spring.

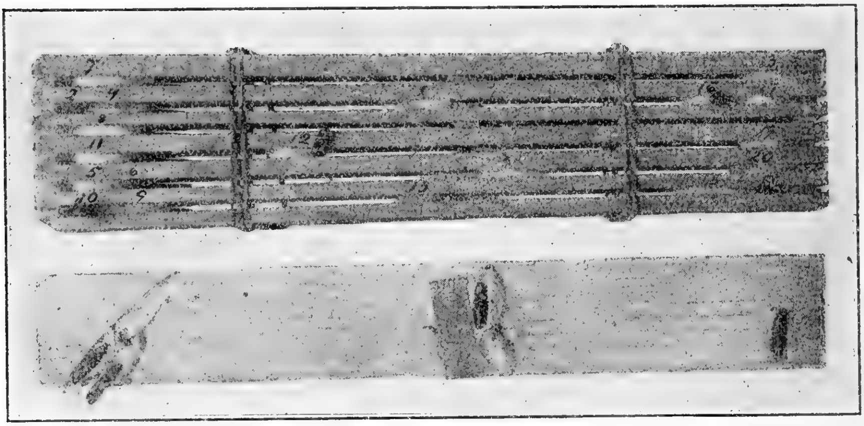

FIG. 18.—Device consisting of strips of wood held together by rubber bands used in obtaining pupal records of the codling moth (*Carpocapsa pomonella*). Reduced. (Original.)

The rearing material for the following emergence of moths, or first-brood moths, was mainly from that used in taking the band records of 1909, and, to a small extent, from reared specimens. There is a special value in the use of band-collected larvæ in the rearing of the codling moth, in that these have up to the time of transforming developed normally in the field and the resulting adults show thus both the normal time of emergence and the relative occurrence in the field.

OVERWINTERING LARVÆ.

The overwintering larvæ of the codling moth in the vicinity of North East, Pa., are partly of the first and partly of the second broods. As is more fully considered on page 84, a portion of the first-brood larvæ, unlike the rest, hibernate—as do normally all larvæ of the second brood—and complete their life cycle the following spring.

PORTION OF OUTDOOR SHELTER USED IN REARING THE CODLING MOTH IN 1909, AT NORTH EAST, PA. (ORIGINAL.)

Unless reared, the larvæ of the two broods can not be separated and are simply referred to as overwintering larvæ. Similarly the resulting pupæ and moths in the spring originate from the two separate broods of the previous year's larvæ, and these are spoken of as "spring-brood pupæ" and "spring-brood moths."

SPRING BROOD OF PUPÆ.

Time of pupation.—In the rearing cages the first observed pupation took place May 24. Considering, however, the time of the earliest record for the emergence of moths, and the duration of the pupal stage, which at that time of the season lasted 24 days, it is probable that pupation must have begun as early as May 20. The last larvæ of the wintering broods pupated June 25. The pupation period thus covered a length of time of over one month (fig. 22). Since the last moth of the spring brood emerged July 17, pupæ were in evidence from May 20 to July 17.

Length of spring pupal stage.—In cage experiments, records were obtained of the duration of the pupal stage for 50 individuals. (See Table I.)

TABLE I.—*Length of pupal periods in spring brood from wintering larvæ, collected during 1908, on banded trees.*

No.	Date of—		Days.	No.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.	
1	May 24	June 17	24	28	May 29	June 21	23
2	May 25	June 16	22	29	May 30	June 22	23
3	...do.....	June 19	25	30	...do.....	June 17	18
4	...do.....	June 28	34	31	May 31	June 22	22
5	May 26	June 17	22	32	...do.....	...do.....	22
6	...do.....	June 20	25	33	...do.....	...do.....	22
7	May 27	...do.....	24	34	...do.....	June 21	21
8	...do.....	...do.....	24	35	...do.....	...do.....	21
9	...do.....	...do.....	24	36	June 1	June 23	22
10	...do.....	June 27	31	37	...do.....	...do.....	22
11	...do.....	June 20	24	38	...do.....	...do.....	22
12	...do.....	...do.....	24	39	...do.....	...do.....	22
13	...do.....	...do.....	24	40	June 2	...do.....	21
14	...do.....	June 14	18	41	...do.....	...do.....	21
15	...do.....	June 20	24	42	...do.....	...do.....	21
16	...do.....	...do.....	24	43	...do.....	...do.....	21
17	...do.....	...do.....	24	44	June 17	July 2	15
18	...do.....	June 14	18	45	...do.....	July 3	16
19	May 28	June 19	22	46	...do.....	July 4	17
20	...do.....	June 20	23	47	June 18	...do.....	16
21	...do.....	...do.....	23	48	June 20	....	......
22	...do.....	June 21	24	49	...do.....	....	......
23	...do.....	June 20	23	50	...do.....	....	......
24	...do.....	June 16	19	51	June 21	July 6	15
25	...do.....	June 21	24	52	June 23	July 8	15
26	May 29	...do.....	23	53	June 25	....	......
27	...do.....	...do.....	23				
			639				438
Total...............			1,077				

The variations in the length of the pupal periods, as shown in Table II, extended from 15 to 30 days.

TABLE II.—*Spring brood of pupæ. Variations in the length of the pupal periods as recorded in Table I.*

Pupæ.	Days.	Pupæ.	Days.
3	15	10	22
2	16	7	23
1	17	12	24
3	18	2	25
1	19	1	31
6	21	1	34

The length of the stages were especially prolonged during the early part of the period of pupation and shortest toward the close of the period, due to a difference in the temperature. In Table III is given a summary of the observations recorded in Table I, showing an average pupal period of 22 days for the total number of observations.

TABLE III.—*Spring brood of pupæ. Summary of pupal periods of Table I.*

Observations.	Days.
Average	21.98
Maximum	34
Minimum	15

SPRING BROOD OF MOTHS.

Time of emergence of moths in the spring.—In figure 19 is shown graphically the time of emergence and the relative occurrence of moths of the spring brood. The records for these observations are given in Table IV.

TABLE IV.—*Emergence of spring moths, 1909, from wintering material collected on banded trees during 1908.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
June 12	1	June 21	31	June 30	13	July 9	4
June 13	....	June 22	23	July 1	25	July 10	2
June 14	5	June 23	50	July 2	15	July 11	1
June 15	3	June 24	40	July 3	3	July 14	2
June 16	6	June 25	50	July 4	5	July 17	1
June 17	13	June 26	33	July 5	10		
June 18	1	June 27	32	July 6	6		486
June 19	10	June 28	35	July 7	8		
June 20	24	June 29	30	July 8	4		

Indoors, moths were observed previous to June 12, but since these undoubtedly had wintered in the house their appearance does not represent normal conditions, as is believed to be the case with material which had been kept out of doors during the winter. The emergence reached its maximum on June 23 and 24, and on July 17 the last moth emerged.

Time of emergence of moths in the spring versus the time wintering larvæ leave the fruit the preceding year.—In Table V is given a detailed

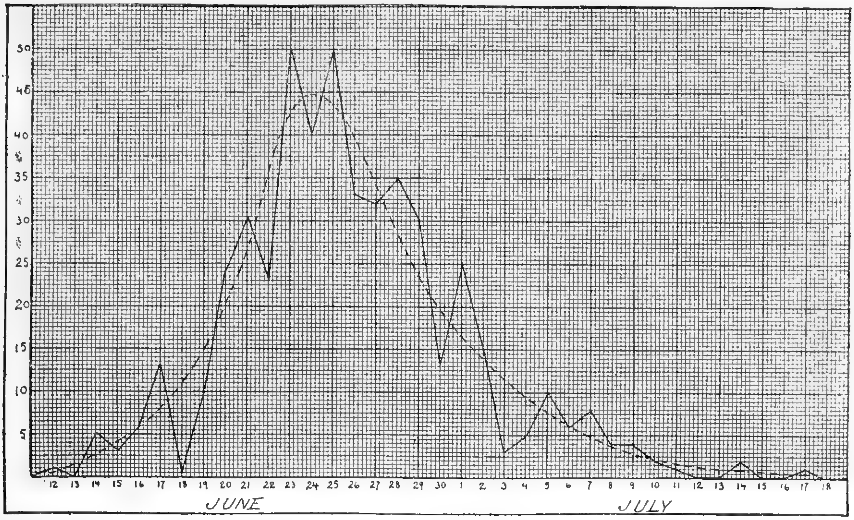

FIG. 19.—Emergence curve showing spring-brood moths in 1909, at North East, Pa. (Original.)

account of the band records of 1908, including the dates of collecting, which extend from July 18 to November 9, and the daily emergence records of moths in the spring of 1909 for the 17 separate band collections.

TABLE V.—*Emergence of moths in 1909, from band material collected during 1908. (The time the larvæ leave the fruit in the fall has no bearing upon the time of emergence of the moths the following spring.)*

Band records.		Records of emergence of moths, 1909.																															Number of moths issued, 1908.	Number of moths issued, 1909.
		June.																		July.														
No.	Date of collecting, 1908.	12.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	14.	17.		
1	July 18										1																						66	1
2	July 25																	1															69	1
3	Aug. 1						1		1	1	1		2	2	1		1		3														87	13
4	Aug. 8					1						2		2	2	5	5	3	2	1				2	1				1				25	27
5	Aug. 14									4	3	3	6	3	3	1	1	1	1	3	1			1			1			1			4	33
6	Aug. 22								2		1	3	6	9	2	2	1	4		1	2				1	1	1	1	1				1	38
7	Aug. 29											1		2	2	1	4				1	1				1					1			14
8	Sept. 5								1	2		3	3	4	1	1	4			2	2			1	1									25
9	Sept. 12			1	2	2		1	6	3	1	5		2	2	6	1	2	2	2	2		1		1		1							43
10	Sept. 19				1	1		1	1	5	4	12	7	12	10	5	7	5	1	3	2	1	1	4	1	4	1	1			1	1		92
11	Sept. 27		1	1	1	1		2	4	5	3	8	4	5	3	4	5	2		5			1		1									56
12	Oct. 3		2	1	1	6		1	2		1	3	3	2	1	1		1	1															26
13	Oct. 12		2			2			4	3	5	1		3	3	1	3	9	2	5	5	1	1											50
14	Oct. 18				1			3		1	1	5	1	1	1	1		1		2				1		1								20
15	Oct. 26	1								2	1		1					1										1						7
16	Nov. 2								1	1																								2
17	Nov. 9																1																	1
	Total ..	1	5	3	6	13	1	8	22	27	22	46	33	47	31	28	33	30	12	24	15	3	4	9	6	7	4	3	2	1	2	1	252	449

The wintering larvæ belonged to both the first and the second broods. It will be seen by a glance at Table V that there was no marked difference in the time of emergence of moths from the first and the second brood larvæ. The division line between the two broods can be approximately determined as between August 29 and September 5, as shown in figure 27.

Time during the day when moths emerged.—When only one daily record of the emergence of the moths is taken, it is of importance to know the time when most moths emerge. A few observations, taken hourly, June 24, from 8.30 a. m. to 8.30 p. m. the same day, and continued, June 26, from 4.30 a. m. to 9.30 a. m., are recorded in Table VI.

TABLE VI.—*Spring brood of moths. Time of emergence during the day.*

Time of observation.		Emergence of moths.	Time of observation.		Emergence of moths.	Time of observation.		Emergence of moths.
Date.	Hour.		Date.	Hour.		Date.	Hour.	
June 24	8.30 a. m.	3	June 24	3.30 p. m.		June 26	4.30 a. m.	
Do.	9.30 a. m.		Do.	4.30 p. m.		Do.	5.30 a. m.	
Do.	10.30 a. m.		Do.	5.30 p. m.		Do.	6.30 a. m.	
Do.	11.30 a. m.	1	Do.	6.30 p. m.		Do.	7.30 a. m.	1
Do.	12.30 p. m.	2	Do.	7.30 p. m.		Do.	8.30 a. m.	1
Do.	1.30 p. m.	1	Do.	8.30 p. m.		Do.	9.30 a. m.	
Do.	2.30 p. m.		June 26					

Nine moths emerged during this period. The first emergence took place about 7.30 a. m. and the last about 1.30 p. m. During the afternoon, evening, and night no moths emerged. More observations on this habit of the moths are desirable in order to establish more accurately the time limits during the day when moths emerge. The above observations, however, suggest the general tendency. Possibly the varying temperature and moisture conditions of the day are influencing factors, because after the process of emerging the parts of the body, and particularly the wings, must expand quickly and assume a normal shape before hardening; in case of extreme dryness the wings may fail to expand.

Period of oviposition.—The moths in confinement frequently fail to oviposit, which is especially the case when a single pair or only a few individual moths are kept together. During the season of 1909 an abundance of eggs was obtained from moths confined in numbers of from 10 to 40 in medium-sized glass jars covered with thin cloth. Each jar contained a layer of moist sand; food, consisting of brown sugar and honey; and for oviposition, apples and apple twigs with foliage were supplied daily. As has been observed by other investigators, the eggs are laid during the evening and the night. In one instance a moth was observed in the act of ovipositing about 9 o'clock in the morning. The eggs were placed in abundance on the apples, the branches, and the foliage, and even on the bottom and on the sides of the jar. The apples and foliage were daily removed and replaced by fresh material, and to avoid infestation from hatching eggs, which had been placed on the sides and bottom of the jars, it became necessary to transfer the moths twice a week into new jars, the old ones being thoroughly cleaned before being put to further use.

In Table VII have been recorded the results from observations on oviposition in 12 rearing jars by moths of a given age. In no instance did oviposition take place until 2 days after the emergence of the moths, and on an average the eggs were first laid during the fourth day after emergence.

TABLE VII.—*Oviposition periods of spring-brood moths in rearing cages.*

Cage No.	Number of moths.	Date of—			Days—		
		Emergence of moths.	First oviposition.	Last oviposition.	Before oviposition.	Length of oviposition.	Between emergence and last oviposition.
1	7	June 16	June 23	June 25	7	3	9
2	10	June 17	June 27	June 29	10	3	12
3	10	June 19	June 24	June 24	5	1	5
4	17	June 20	June 23	June 30	3	8	10
5	11	June 21	June 24	June 29	3	6	8
6	10	June 22	June 25	July 1	3	7	9
7	39	June 23	...do.....	July 6	2	12	13
8	18	June 24	June 27	July 5	3	9	11
9	37	June 25	...do.....	July 7	2	11	12
10	23	June 29	July 7	July 15	8	9	16
11	15	July 1	July 5	...do.....	4	11	14
12	4	July 7	July 12	July 21	5	10	14
	201				55	90	133

The length of oviposition for each jar varied from 1 to 11 days, with an average of 7 days for the entire number of rearing jars. In one instance oviposition took place the sixteenth day after the date of emergence of the moths. On an average, however, oviposition extended to 11 days after emergence.

TABLE VIII.—*Oviposition periods of spring-brood moths. Summary of Table VII.*

Observations.	Days before oviposition.	Days of oviposition.	Days between emergence and last oviposition.
Average	4.6	7.5	11.08
Maximum	10	12	16
Minimum	2	1	5

In view of the abundance of eggs deposited and the manner in which they were laid, it was impossible to determine the number for a given moth. In the field the relative abundance of eggs during the season must be approximately in proportion to the occurrence of moths (fig. 19). In the rearing jars eggs were obtained from June 23 to July 15. Considering, however, the above observations on oviposition and the time of emergence of the first moths, it can closely and with some degree of accuracy be estimated that eggs were laid in the field from about June 17 to about July 22.

Length of life of the moth.—Records were kept relative to the length of life of the moths which were confined in jars for oviposition. The results of these observations are given in Table IX, with a summary in Tables X and XI showing the extent of variation in the length of life of 161 moths.

TABLE IX.—*Length of life of moths of the spring brood in rearing cages.*

Number of moths.	Date of— Emergence.	Date of— Death.	Days.	Number of moths.	Date of— Emergence.	Date of— Death.	Days.
6	June 21	July 2	11	1	June 25	July 12	17
3	...do.....	July 4	13	1	...do.....	July 14	19
2	...do.....	July 7	16	5	June 29	July 10	11
6	June 22	July 2	10	2	...do.....	July 11	12
3	...do.....	July 3	11	5	...do.....	July 12	13
1	...do.....	July 9	17	2	...do.....	July 13	14
21	June 23	July 2	9	2	...do.....	July 14	15
2	...do.....	July 3	10	2	...do.....	July 15	16
4	...do.....	July 4	11	5	...do.....	July 16	17
6	...do.....	July 5	12	4	July 1	July 11	10
5	...do.....	July 10	17	5	...do.....	July 12	11
1	...do.....	July 12	19	2	...do.....	July 13	12
10	June 24	July 1	7	3	...do.....	July 15	14
4	...do.....	July 5	11	1	...do.....	July 16	15
2	...do.....	July 7	13	4	July 5	July 12	7
10	June 25	July 2	7	2	...do.....	July 14	9
7	...do.....	July 5	10	2	...do.....	July 16	11
7	...do.....	July 6	11	1	...do.....	July 20	15
4	...do.....	July 7	12	1	...do.....	July 22	17
1	...do.....	July 9	14	2	July 7	July 16	9
1	...do.....	July 10	15	1	...do.....	July 17	10
1	...do.....	July 11	16	1	...do.....	July 22	15

TABLE X.—*Length of life of moths of the spring brood. Summary of Table IX.*

Number of moths.	Days per moth.	Days for total number of moths.	Number of moths.	Days per moth.	Days for total number of moths.
24	7	168	6	15	90
25	9	225	5	16	80
20	10	200	13	17	221
36	11	396	2	19	38
14	12	168			
10	13	130	161	....	1,800
6	14	84			

TABLE XI.—*Length of life of moths of the spring brood. Summary of Table IX.*

Observations.	Days.
Average......................	11.18
Maximum......................	19
Minimum......................	7

It is evident from this table that the greater number died shortly after the first week after emergence. On an average the moths lived 11 days; 2 moths lived 19 days and 24 moths lived 7 days.

THE FIRST GENERATION.

FIRST-BROOD EGGS.

Incubation period.—In the preceding pages the time and extent of egg deposition have been considered as habits of the moths. In view of the abundance of eggs laid on the apples in the cages, it was not possible to count the eggs and determine the incubation period for individual eggs. But, as shown in Table XII, records were taken at the time of hatching of the first and the last eggs of each group of apples containing eggs of a given age, which merely shows in a general way the extent of the variability during the incubation.

TABLE XII.—*First-brood eggs. Incubation period of eggs laid in rearing cages.*

No. of observation.	Date of— Deposition.	Date of— Hatching.	Days of incubation.	No. of observation.	Date of— Deposition.	Date of— Hatching.	Days of incubation.
1	June 23	June 29	6	19	July 3	July 12	9
2	June 24	...do...	5	20	July 4	...do...	8
3	June 25	July 1	6	21	July 5	...do...	7
4	...do...	July 2	7	22	...do...	July 13	8
5	June 26	...do...	6	23	July 6	...do...	7
6	...do...	July 3	7	24	July 8	July 14	6
7	June 27	July 4	7	25	...do...	July 15	7
8	...do...	July 5	8	26	July 9	...do...	6
9	June 28	July 6	8	27	July 10	...do...	5
10	June 29	July 7	8	28	...do...	July 16	6
11	...do...	July 8	9	29	July 11	...do...	5
12	...do...	July 9	10	30	...do...	July 17	6
13	June 30	July 8	8	31	July 12	July 18	6
14	July 1	July 9	8	32	...do...	July 19	7
15	...do...	July 10	9	33	July 13	July 21	8
16	...do...	July 11	10	34	July 14	...do...	7
17	July 2	...do...	9	35	...do...	July 22	8
18	...do...	July 12	10	36	July 15	...do...	7

The difference of one to two days in the time of hatching indicates an existing difference in the embryological development originating previous to the time of oviposition. Similar observations were made in 1909 by the writer with eggs of the grape root-worm which had all been laid by a single female at the same time. On hatching, these eggs showed a variation of 2 days in the time of incubation. Table XII, representing a summary of observations of the previous table, shows an average of 7.33 days for the entire egg period, with a maximum of 10 days and a minimum of 5 days.

TABLE XIII.—*Incubation period of first-brood eggs. Summary of Table XII.*

Observations.	Days of incubation.
Average	7.33
Maximum	10
Minimum	5

FIRST-BROOD LARVÆ.

As has been already stated, some of the first-brood larvæ do not transform with the rest of the brood, but spin up for the winter, hibernating along with second-brood larvæ. In the rearing of the codling moth separate observations were made for the two sets of larvæ, which are here treated separately as "transforming" and "wintering" larvæ.

Time of hatching.—In the rearing cages the first larvæ hatched June 30, but these were not from eggs of the earliest moths, as the latter failed to oviposit in captivity. Considering, however, the emergence and oviposition records of the moths, previously described, it is very probable that eggs occurred in the field on June 23 and continued to appear until the end of July. In the rearing cages the last larvæ of the brood hatched June 22, while in the field two newly hatched larvæ were found in apples as late as July 25.

Number of larvæ developing in each apple.—In the rearing of the codling moth great numbers of young larvæ entered the same apple, but when the apples were examined at the time of maturity of the larvæ only one or, rarely, two or three larvæ were found in the same fruit. In orchards usually only a single larva is found in each apple, although the apples may show several empty eggshells and entrance places of the young larvæ. The writer observed, on July 2, 1909, in the course of rearing the grape-berry moth (*Polychrosis viteana* Clemens), how a newly hatched larva devoured another of its own kind, both having emerged at about the same time. It is very probable that where larvæ of the codling moth occur in numbers many of them meet a similar fate.

Period of feeding of transforming larvæ.—In Table XXII are given the feeding periods of 53 individual larvæ which were reared in cages. On an average the larvæ remained in the fruit 26 days, a single larva remained 37 days, while the shortest period in the fruit was 17 days. (See Table XXIII.)

Period of feeding of wintering larvæ of the first brood.—On an average the wintering larvæ of the first brood remained 31 days in the fruit, while the transforming larvæ remained only 26 days. (See Table XVI.) Records of the feeding period for about 200 wintering larvæ were taken from observations in rearing cages, as shown in Table XIV.

TABLE XIV.—*Larvæ of the first brood. Feeding periods of wintering larvæ.*

Number of larvæ.	Date—Hatched.	Date—Left fruit.	Days feeding.	Number of larvæ.	Date—Hatched.	Date—Left fruit.	Days feeding.	Number of larvæ.	Date—Hatched.	Date—Left fruit.	Days feeding.
1	June 30	July 25	25	7	July 8	Aug. 5	28	1	July 13	Aug. 9	27
1	...do.....	July 28	28	1	...do.....	Aug. 6	29	4	...do.....	Aug. 10	28
1	...do.....	July 30	30	3	...do.....	Aug. 8	31	3	...do.....	Aug. 13	31
1	...do.....	July 31	31	1	...do.....	Aug. 10	33	1	...do.....	Aug. 14	32
1	...do.....	Aug. 9	40	1	...do.....	Aug. 11	34	2	...do.....	Aug. 16	34
2	...do.....	Aug. 11	42	1	...do.....	Aug. 12	35	2	...do.....	Aug. 17	35
1	...do.....	July 29	29	1	...do.....	Aug. 13	36	1	...do.....	Aug. 12	30
1	...do.....	July 30	30	1	July 9	July 28	[a] 19	2	...do.....	Aug. 15	33
1	...do.....	July 31	31	1	...do.....	Aug. 2	24	1	...do.....	Aug. 17	35
1	July 1	July 26	25	3	...do.....	Aug. 3	25	1	...do.....	Aug. 20	38
2	...do.....	July 29	28	2	...do.....	Aug. 4	26	1	July 15	Aug. 12	28
1	...do.....	July 31	30	3	...do.....	Aug. 9	31	3	...do.....	Aug. 13	29
2	...do.....	Aug. 2	32	2	...do.....	Aug. 15	37	2	...do.....	Aug. 15	31
1	...do.....	Aug. 4	34	1	...do.....	Aug. 28	50	1	...do.....	Aug. 16	32
1	...do.....	Aug. 17	47	1	July 10	July 26	[a] 16	1	...do.....	Aug. 13	29
1	July 2	July 31	29	1	...do.....	Aug. 4	25	1	...do.....	Aug. 14	30
2	...do.....	Aug. 2	31	1	...do.....	Aug. 5	26	1	...do.....	Aug. 15	31
1	...do.....	Aug. 5	34	1	...do.....	Aug. 8	29	2	...do.....	Aug. 16	32
1	...do.....	Aug. 11	40	1	...do.....	Aug. 11	32	2	...do.....	Aug. 17	33
1	...do.....	Aug. 14	43	1	July 11	July 28	[a] 17	1	...do.....	Aug. 18	34
2	July 4	July 31	27	1	...do.....	Aug. 3	23	2	...do.....	Aug. 21	37
1	...do.....	Aug. 1	28	1	...do.....	Aug. 5	25	1	...do.....	Aug. 22	38
1	...do.....	Aug. 2	29	2	...do.....	Aug. 8	28	1	...do.....	Aug. 27	43
3	...do.....	Aug. 3	30	1	...do.....	Aug. 9	29	2	July 17	Aug. 14	28
2	...do.....	Aug. 5	32	1	...do.....	Aug. 11	31	2	...do.....	Aug. 15	29
2	...do.....	Aug. 9	36	1	...do.....	Aug. 14	34	3	...do.....	Aug. 16	30
1	...do.....	Aug. 11	38	1	...do.....	Aug. 15	35	1	...do.....	Aug. 21	35
1	...do.....	Aug. 21	48	1	...do.....	Aug. 16	36	1	...do.....	Aug. 26	40
2	July 6	Aug. 2	27	1	...do.....	Aug. 18	38	1	July 19	Aug. 12	24
1	...do....	Aug. 3	28	1	July 12	Aug. 6	25	2	...do.....	Aug. 14	26
7	...do.....	Aug. 4	29	2	...do.....	Aug. 8	27	3	...do.....	Aug. 15	27
2	...do.....	Aug. 5	30	1	...do.....	Aug. 15	34	2	...do.....	Aug. 16	28
4	...do.....	Aug. 8	31	1	...do.....	Aug. 17	36	4	...do.....	Aug. 21	33
4	...do.....	Aug. 9	34	1	...do.....	Aug. 2	21	1	...do.....	Aug. 22	34
4	...do.....	Aug. 10	35	1	...do.....	Aug. 10	29	1	...do.....	Aug. 24	36
1	...do.....	Aug. 21	46	1	...do.....	Aug. 14	33	1	...do.....	Aug. 26	38
1	...do.....	Aug. 22	47	1	...do.....	Aug. 20	39	1	...do.....	Aug. 27	39
1	...do.....	Aug. 30	55	1	July 13	July 27	[a] 14	2	July 21	Aug. 16	26
1	July 8	July 25	[a] 17	1	...do.....	July 6	24	2	...do.....	Aug. 20	30
1	...do.....	Aug. 2	25	1	...do.....	July 7	25	1	...do.....	Aug. 23	33
1	...do.....	Aug. 3	26	1	...do.....	July 8	26	1	...do.....	Aug. 26	36

[a] Probably previously infested apple.

Summaries as to length of feeding for both transforming and wintering larvæ are shown comparatively in Tables XV and XVI.

TABLE XV.—*Larvæ of the first brood. Comparison of the feeding periods of transforming and wintering larvæ. Summary of Tables XIV and XXII.*

Transforming larvæ.			Wintering larvæ.		
Number of larvæ.	Days per larva.	Days for total number of larvæ.	Number of larvæ.	Days per larva.	Days for total number of larvæ.
1	a 14	14	1	a 14	14
....	15	....	1	a 16	16
....	16	....	2	17	34
2	17	34	1	19	19
1	18	18	1	21	21
....	19	....	1	23	23
....	20	....	3	24	74
....	21	....	10	25	250
6	22	132	9	26	234
3	23	69	10	27	270
3	24	72	23	28	644
5	25	125	20	29	580
3	26	78	15	30	450
7	27	189	17	31	527
5	28	140	10	32	320
5	29	145	16	33	528
3	30	90	13	34	442
4	31	124	8	35	280
2	32	64	7	36	252
2	33	66	4	37	148
....	34	....	5	38	190
....	35	....	2	39	78
....	36	....	3	40	120
1	37	37	2	42	82
....	....	....	2	43	86
....	....	....	1	46	46
....	....	....	2	47	94
....	....	....	1	48	48
....	....	....	1	50	50
....	....	....	1	55	55
53	....	1,397	192	....	5,975

a Probably from infested apple.

TABLE XVI.—*Larvæ of the first brood. Comparison of the feeding periods of transforming and wintering larvæ. Summary of Table XV.*

Observations.	Days of feeding of—	
	Transforming larvæ.	Wintering larvæ.
Average	26.36	31.10
Maximum	37	55
Minimum	17	17

TABLE XVII.—*Larvæ of the first brood. Percentage of transforming and wintering larvæ of cage material.*

Cage No.	Number of larvæ.			Cage No.	Number of larvæ.		
	Transforming.	Wintering.	Total.		Transforming.	Wintering.	Total.
1........	11	7	18	13........	5	17	22
2........	4	3	7	14........	....	6	6
3........	9	8	17	15........	....	7	7
4........	9	6	15	16........	....	12	12
5........	14	13	27	17........	....	9	9
6........	9	27	36	18........	....	19	19
7........	2	17	19	19........	1	8	9
8........	5	14	19				
9........	7	6	13	Total..	85	199	284
10........	5	11	16				
11........	2	5	7	Per cent..	29.93	70.07	100.00
12........	2	4	6				

Time of maturity of transforming larvæ.—From apples collected in an orchard July 8 the first larvæ emerged July 10, while from banded trees larvæ were obtained three days later. In the rearing cages the last transforming larva left the fruit August 14. (See Tables XXII and XXXIII, and fig. 22.)

Time of maturity of wintering larvæ.—Of the band record material of 1909 two larvæ, which had been collected July 19, did not transform with the rest of the brood, but remained in the larval stage and wintered. The second-brood larvæ first appear about September 10. (See fig. 22.) On examining the results of the band records, as presented in figure 21, it will be noted that the greater number of larvæ belonged to the first brood, and that the period of maturation of these larvæ extended from early July to the close of September, or perhaps even to the early part of October.

Percentages of transforming and of wintering larvæ of the first brood.—In Table XVII is given a summary of breeding experiments, showing the comparative number of transforming and wintering larvæ of the first brood. From these observations it will be found that in number the wintering larvæ exceeded the transforming larvæ about two and one-half times. These results agree closely with those obtained from the band material, which is a better test of the relative occurrence of larvæ in the field. (See Table XXXIV.) Of the first brood 23.46 per cent of the larvæ transformed and 76.54 per cent wintered. Considering the two parallel records of both cage-reared larvæ, the first brood consisted thus of one-third of transforming larvæ and two-thirds of wintering larvæ.

Larval life in the cocoon.—Cage records were kept relative to the time of leaving the fruit and the time of pupation of 52 individual larvæ. This period includes the time for the making of the cell and the so-called post-larval stage, which consists of an inactive period of one or two days, when the larva undergoes structural changes previous to pupation. A definite time limit for the post-larval stage can hardly be given, since this is a gradual change, which leads up to pupation. In Table XXII the larval life of the cocoon has been referred to under the making of the cocoon, as this constitutes the main activity of the larva during this period, but it also included the post-larval stage. The summary of the larval life in the cocoon, as recorded in Table XXIII, agrees in a striking manner with the records obtained by Mr. E. L. Jenne [a] in Arkansas in 1908. For North East, Pa., the average was 7.09 days, the maximum 19 days, and the minimum 3 days. Mr. Jenne's records show an average of 7.2 days, maximum 19 days, and minimum 3 days. In instances where the entire period previous to pupation has been recorded to last only three days, it is very probable that the larvæ, when disturbed in the process of making the cocoons, abandoned the first cocoons and made new ones. The period, therefore, appears shorter, as no record was kept of the time required in making the first cocoon.

FIRST-BROOD PUPÆ.

Time of pupation.—From infested apples, collected in an orchard July 8, mature larvæ emerged July 10 which pupated July 16. From the band material pupæ were obtained a few days later and were observed in abundance throughout the period. The last pupation occurred in the cages August 27. These late-appearing pupæ, however, failed to develop, moths emerging only from larvæ that pupated not later than August 19.

Length of first-brood pupal stage.—Of 95 pupæ of the first brood, the average duration of the stage was 12.5 days, ranging from 6 to 22 days. (See Table XX.) The records for the individual pupæ are given in Table XVIII, with a summary in Table XIX, showing variations observed in the length of the stages during the entire period when pupæ were found.

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[a] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part I.

TABLE XVIII.—*Pupæ of the first brood. Length of the pupal periods, from material collected in 1909, on banded trees.*

No.	Date of—		Days.	No.	Date of—		Days.	No.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.			Pupation.	Emergence.	
1	July 17	Aug. 2	16	33	July 28	Aug. 7	10	65	Aug. 6	Aug. 22	16
2	July 18	Aug. 3	16	34	July 29	Aug. 8	10	66	Aug. 7	Aug. 18	11
3	...do....	Aug. 2	15	35	...do....	Aug. 7	9	67	...do....	...do....	11
4	...do....	Aug. 3	16	36	...do....	Aug. 9	11	68	...do....	Aug. 19	12
5	July 19	Aug. 2	14	37	July 30	...do....	10	69	...do....	...do....	12
6	...do....	Aug. 3	15	38	...do....	...do....	10	70	...do....	Aug. 20	13
7	July 20	Aug. 2	13	39	...do....	Aug. 11	12	71	...do....	...do....	13
8	July 22	Aug. 3	12	40	...do....	Aug. 12	13	72	Aug. 8	Aug. 23	15
9	...do....	Aug. 4	13	41	July 31	Aug. 14	14	73	Aug. 9	...do....	14
10	...do....	Aug. 3	12	42	...do....	...do....	14	74	Aug. 10	Aug. 26	16
11	...do....	Aug. 4	13	43	...do....	Aug. 13	13	75	...do....	Aug. 25	15
12	...do....	Aug. 3	12	44	...do....	Aug. 11	11	76	...do....	...do....	15
13	July 23	Aug. 5	13	45	Aug. 2	Aug. 9	7	77	...do....	...do....	15
14	...do....	Aug. 4	12	46	...do....	...do....	7	78	...do....	...do....	15
15	...do....	Aug. 5	13	47	...do....	Aug. 8	6	79	...do....	...do....	15
16	...do....	...do....	13	48	Aug. 3	Aug. 11	8	80	...do....	...do....	15
17	...do....	...do....	13	49	...do....	Aug. 10	7	81	Aug. 11	Aug. 26	15
18	...do....	...do....	13	50	...do....	...do....	7	82	...do....	...do....	15
19	...do....	...do....	13	51	...do....	...do....	7	83	...do....	Aug. 27	16
20	...do....	Aug. 6	14	52	...do....	Aug. 12	9	84	...do....	Aug. 25	14
21	...do....	Aug. 5	13	53	...do....	Aug. 13	10	85	Aug. 12	Aug. 26	14
22	...do....	Aug. 4	12	54	...do....	Aug. 14	11	86	...do....	...do....	14
23	July 24	Aug. 6	13	55	...do....	...do....	11	87	...do....	...do....	14
24	July 25	...do....	12	56	...do....	Aug. 12	9	88	...do....	Aug. 25	13
25	...do....	Aug. 7	13	57	...do....	Aug. 11	8	89	...do....	Aug. 26	14
26	...do....	...do....	13	58	...do....	Aug. 13	10	90	...do....	...do....	14
27	July 26	...do....	12	59	Aug. 5	Aug. 17	12	91	Aug. 16	Aug. 30	14
28	...do....	...do....	12	60	...do....	Aug. 18	13	92	Aug. 17	Aug. 31	14
29	July 27	Aug. 8	12	61	...do....	...do....	13	93	...do....	Sept. 2	16
30	...do....	...do....	12	62	...do....	Aug. 15	10	94	Aug. 19	Sept. 6	18
31	...do....	Aug. 9	13	63	Aug. 6	Aug. 28	22	95	Aug. 23	....	......
32	July 28	Aug. 8	11	64	...do....	Aug. 20	14				1,185

TABLE XIX.—*Pupæ of the first brood. Variations of pupal periods. Summary of Table XVIII.*

Number of pupæ.	Pupal period (days).	Number of pupæ.	Pupal period (days).	Number of pupæ.	Pupal period (days).	Number of pupæ.	Pupal period (days).
1	6	7	10	21	13	7	16
5	7	7	11	14	14	1	18
2	8	14	12	11	15	1	22
3	9						

TABLE XX.—*Pupæ of the first brood. Length of pupal periods. Summary of Table XVIII.*

Observations.	Pupal period (days).
Average	12.5
Maximum	22
Minimum	6

FIRST-BROOD MOTHS.

Time of emergence.—On August 2 the earliest first-brood moths emerged from band material collected July 13. As shown in figure 20 and Table XXI, the moths gradually increased in number, reaching a maximum on August 26, at which time moths suddenly decreased, emergence ceasing altogether about September 3.

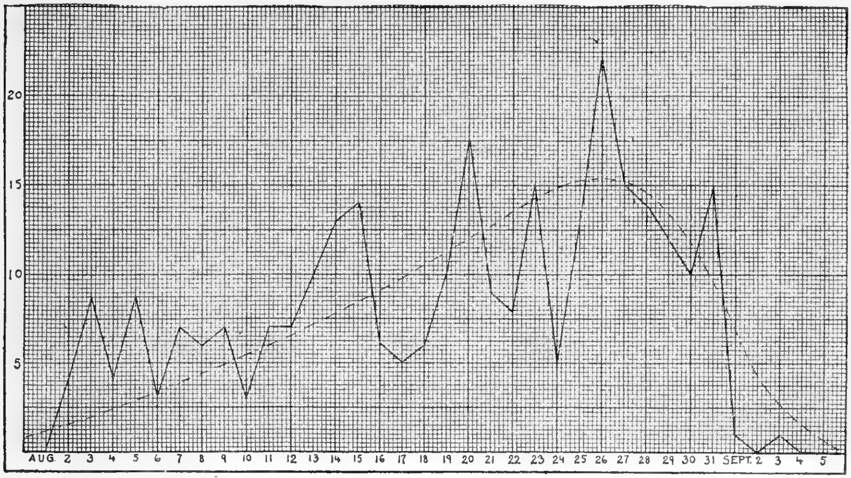

FIG. 20.—Emergence curve showing first-brood moths, in 1909, at North East, Pa. (Original.)

TABLE XXI.—*Emergence of moths of the first brood. Material from banded trees.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
Aug. 2	4	Aug. 11	7	Aug. 20	18	Aug. 28	14
Aug. 3	8	Aug. 12	7	Aug. 21	9	Aug. 29	12
Aug. 4	4	Aug. 13	10	Aug. 22	8	Aug. 30	10
Aug. 5	8	Aug. 14	13	Aug. 23	15	Aug. 31	5
Aug. 6	3	Aug. 15	14	Aug. 24	5	Sept. 2	1
Aug. 7	7	Aug. 16	7	Aug. 25	13	Sept. 3	1
Aug. 8	5	Aug. 17	5	Aug. 26	22		
Aug. 9	7	Aug. 18	6	Aug. 27	15		276
Aug. 10	3	Aug. 19	10				

It is of interest to note that the rate of emergence of the spring-brood moths is almost the reverse of the rate of emergence of the first-brood moths. In the spring, shortly after the appearance of the first moths, the maximum is attained within about a week, while the decrease in the number of moths is more gradual and extends over a longer period.

Oviposition period.—For oviposition records moths of this brood were confined in rearing jars, as has already been described for the spring brood of moths (p. 77). As shown in Table XXIV, the observations include twenty-six separate jars, in which the number of moths varied from 3 to 17 for each jar. In five of the jars no eggs were obtained, while in the rest eggs were deposited in greater or less abundance. In the summary of the oviposition records (Table XXV) it may be observed that on an average the moths first oviposited 5 days after their emergence; in one instance this period extended to 13 days; the earliest oviposition took place 2 days after emergence. The length of oviposition in the various jars lasted, on an average, 7 days, with a maximum of 15 days and a minimum of 1 day. From the time of emergence of the moth the last oviposition in the various jars took place, on an average, the eleventh day, the longest time being 19 days and the shortest 6 days. On comparing the oviposition records of observations for the two broods of moths (Tables VIII and XXV) it will be noted that the records show practically similar results.

The oviposition period extended from August 6—the fifth day after the emergence of the first moth—to September 22. Of the late deposited eggs only those laid previous to September 12 hatched, as the prevailing cold weather at that time stopped further developments.

Length of life of individual male and female moths.—In the various stock jars which were used in the oviposition experiments records were kept as to the length of life of 57 male and 92 female moths. As has already been described in connection with the spring brood, moths of the first brood were similarly fed with brown sugar and honey and received daily fresh apples and apple foliage for oviposition. Summaries of the results of these observations are given in Tables XXVI and XXVII. The average length of life for the male moths was 9.79 days, and for the female moths 11.47 days.

LIFE CYCLE OF THE FIRST GENERATION.

In connection with the various rearing experiments for the separate stages of the first generation a set of experiments was conducted, carrying individual insects through a complete life cycle. The results of these observations (see Tables XXII and XXIII) agree closely with the sum total of the averages of observations on the separate stages.

TABLE XXII.—*Life cycle of the first generation, as determined by rearing during 1909.*

No. of observation.	Date of— Egg deposition.	Date of— Hatching.	Date of— Larva leaving the fruit.	Date of— Pupation.	Date of— Emergence of moth.	Days for— Hatching.	Days for— Feeding.	Days for— Making of cocoon.	Days for— Pupal period.	Days for— Total life cycle.
1	June 23	June 30	July 27	Aug. 5	Aug. 20	7	27	9	15	58
2	...do.....	...do.....	...do.....	Aug. 3	Aug. 18	7	27	7	15	56
3	...do.....	...do.....	...do.....	Aug. 2	Aug. 15	7	27	6	13	53
4	...do.....	...do.....	...do.....	...do.....	...do.....	7	27	6	13	53
5	...do.....	...do.....	July 28	Aug. 8	Aug. 23	7	28	11	15	61
6	...do.....	...do.....	...do.....	Aug. 4	Aug. 16	7	28	7	12	54
7	...do.....	...do.....	...do.....	Aug. 3	Aug. 17	7	28	6	14	55
8	...do.....	...do.....	July 29	Aug. 5	Aug. 19	7	29	7	14	57
9	...do.....	...do.....	...do.....	Aug. 9	Aug. 23	7	29	11	14	61
10	...do.....	...do.....	July 30	....	Aug. 15	7	30	....	....	53
11	June 24	...do.....	July 22	July 29	Aug. 9	6	22	7	11	46
12	...do.....	...do.....	...do.....	July 28	Aug. 11	6	22	6	14	48
13	...do.....	...do.....	...do.....	...do.....	...do.....	6	22	6	14	48
14	...do.....	...do.....	July 27	July 30	...do.....	6	27	3	12	48
15	June 25	July 1	Aug. 1	Aug. 9	Aug. 20	6	31	8	11	56
16	...do.....	...do.....	Aug. 3	...do.....	Aug. 23	6	33	6	14	59
17	June 26	July 2	July 19	July 23	Aug. 3	6	17	4	11	38
18	...do.....	...do.....	...do.....	...do.....	Aug. 5	6	17	4	13	40
19	...do.....	...do.....	Aug. 3	Aug. 9	Aug. 24	6	32	6	15	59
20	...do.....	...do.....	Aug. 8	Aug. 13	Aug. 29	6	37	5	16	64
21	June 27	July 4	July 22	July 28	Aug. 9	7	18	6	12	43
22	...do.....	...do.....	July 30	Aug. 8	Aug. 23	7	26	9	15	57
23	June 28	July 6	July 28	Aug. 2	....	8	22	5	....	....
24	...do.....	...do.....	July 29	Aug. 6	....	8	23	8	....	....
25	...do.....	...do.....	July 31	Aug. 7	....	8	25	7	....	....
26	...do.....	...do.....	Aug. 1	Aug. 6	Aug. 19	8	26	5	13	52
27	...do.....	...do.....	Aug. 3	Aug. 9	....	8	28	6	....	....
28	...do.....	...do.....	Aug. 4	Aug. 10	Aug. 25	8	29	6	15	58
29	...do.....	...do.....	Aug. 5	Aug. 8	....	8	30	3	....	....
30	June 29	July 8	Aug. 1	...do.....	Aug. 19	9	24	7	11	51
31	June 30	July 9	Aug. 2	Aug. 15	Aug. 28	9	24	13	13	59
32	...do.....	...do.....	Aug. 4	Aug. 8	....	9	26	4	....	....
33	...do.....	...do.....	Aug. 9	Aug. 11	....	9	31	2	....	....
34	...do.....	...do.....	...do.....	Aug. 26	....	9	31	17	....	....
35	...do.....	...do.....	Aug. 10	Aug. 14	....	9	32	4	....	....
36	July 1	July 10	Aug. 1	Aug. 16	Aug. 31	9	22	15	15	61
37	...do.....	...do.....	...do.....	Aug. 9	Aug. 23	9	22	8	14	53
38	...do.....	...do.....	Aug. 6	Aug. 16	Aug. 30	9	27	10	14	60
39	...do.....	...do.....	Aug. 8	Aug. 27	....	9	29	19	....	....
40	...do.....	...do.....	...do.....	Aug. 18	Sept. 3	9	29	10	16	64
41	July 2	July 11	July 25	July 31	Aug. 14	9	a 14	6	14	43
42	...do.....	...do.....	Aug. 5	Aug. 11	....	9	25	6	....	....
43	...do.....	...do.....	Aug. 10	Aug. 22	....	9	30	12	....	....
44	July 3	July 12	Aug. 5	Aug. 12	....	9	24	7	....	....
45	...do.....	...do.....	Aug. 14	Aug. 19	....	9	33	5	....	....
46	July 4	...do.....	Aug. 4	Aug. 8	Aug. 22	8	23	4	14	49
47	...do.....	...do.....	Aug. 6	Aug. 9	....	8	25	3	....	....
48	July 5	July 13	Aug. 7	Aug. 11	....	8	25	4	....	....
49	...do.....	...do.....	...do.....	Aug. 13	Aug. 27	8	25	6	14	53
50	...do.....	...do.....	Aug. 9	Aug. 16	....	8	27	7	....	....
51	...do.....	...do.....	Aug. 10	Aug. 14	Aug. 28	8	28	4	14	54
52	...do.....	...do.....	Aug. 13	Aug. 18	....	8	31	5	....	....
53	July 13	July 21	...do....	Aug. 23	....	8	23	10	....	....
						408	1,397	368	450	1,824

a Probably from infested apple.

TABLE XXIII.—*Life cycle of the first generation. Summary of Table XXII.*

Observations.	Days for— Hatching.	Days for— Feeding.	Days for— Making of cocoon.	Days for— Pupal period.	Days for— Total life-cycle.
Average..................	7.7	26.36	7.09	13.63	53.64
Maximum..................	9	37	19	16	64
Minimum..................	6	17	3	11	38

Since the life cycle is considered to begin with the appearance of the eggs, it becomes first completed with the appearance of eggs from moths of the same generation. The average period between the emergence of moths and first oviposition must therefore be added to the life cycle and not, as might be thought, the length of life of the moth (see Tables XXVI and XXVII). The sum total of the averages for the stages together with the average of 5 days for the oviposition (see Tables XXIV and XXV) makes 58.28 days; the average for the life cycle of individuals reared through all stages together with 5 days for oviposition was 58.68 days.

TABLE XXIV.—*Oviposition periods of moths of the first brood in rearing cages.*

Cage No.	Number of moths.	Date of— Emergence of moth.	Date of— First oviposition.	Date of— Last oviposition.	Days— Before oviposition.	Days— Length of oviposition.	Days— Between emergence and last oviposition.
1	4	Aug. 2	Aug. 9	Aug. 12	7	4	10
2	7	Aug. 3	Aug. 6	Aug. 9	3	4	6
3	4	Aug. 4	Aug. 7	Aug. 10	3	4	6
4	8	Aug. 5	...do.....	Aug. 20	2	14	15
5	3	Aug. 6	Aug. 13	Aug. 13	7	1	7
6	8	Aug. 7	Aug. 9	Aug. 20	2	12	13
7	3	Aug. 8	....	....	....	....	....
8	7	Aug. 9	Aug. 13	Aug. 25	4	13	16
9	4	Aug. 10	....	....	....	....	....
10	6	Aug. 11	Aug. 16	Aug. 20	5	5	9
11	3	Aug. 12	Aug. 25	Aug. 26	13	2	14
12	4	Aug. 14	....	....	....	....	....
13	4	Aug. 15	Aug. 19	Aug. 21	4	3	6
14	4	Aug. 16	Aug. 20	Aug. 26	4	7	10
15	5	Aug. 17	Aug. 24	Aug. 27	7	4	10
16	7	Aug. 18	Aug. 22	Aug. 28	4	7	10
17	12	Aug. 19	...do.....	Aug. 29	3	8	10
18	17	Aug. 20	Aug. 25	Aug. 31	5	7	11
19	10	Aug. 21	...do.....	Sept. 9	4	15	19
20	14	Aug. 23	....	....	....	....	....
21	11	Aug. 25	Aug. 28	Sept. 4	3	8	10
22	10	Aug. 27	Aug. 30	Sept. 11	3	13	15
23	9	Aug. 29	Sept. 2	Sept. 12	5	11	14
24	6	Aug. 30	....	....	....	....	....
25	4	Sept. 3	Sept. 11	Sept. 15	8	5	12
26	6	Sept. 6	Sept. 15	Sept. 22	9	8	16
					105	155	239

TABLE XXV.—*Oviposition periods of moths of the first brood. Summary of Table XXIV.*

Observations.	Days— Before first oviposition.	Days— Length of oviposition.	Days— Between emergence and last oviposition.
Average..................	5.0	7.38	11.38
Maximum..................	13	15	19
Minimum..................	2	1	6

TABLE XXVI.—*Longevity of male and female moths of the first brood. Summary of records of 149 individual moths.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*	
2	3	2	1	14	2	14	7
3	1	3	4	15	3	15	3
4	3	4	2	16	3	16	6
5	1	5	2	17	2	17	7
6	1	6	4	18	1	18	2
7	5	7	6	....	....	19	1
8	6	8	5	....	....	20	1
9	9	9	4	....	....	21	1
10	4	10	9	....	....	22	2
11	3	11	8				
12	5	12	7		57		92
13	5	13	10				

TABLE XXVII.—*Longevity of male and female moths of the first brood. Summary of Table XXVI.*

Observations.	Life of male moths.	Life of female moths.
	Days.	*Days.*
Average	9.79	11.47
Maximum	18	22
Minimum	2	2

On further testing the rearing results by taking the dates of the maximum emergence of the spring brood of moths (June 24) and the emergence of moths of the first brood (August 26) it will be found that 63 days elapsed. But since the emergence of moths of the first brood was very gradual, reaching its maximum first at the close of the season (fig. 22), it becomes evident that the average of 58.5 days is fairly accurate.

THE SECOND GENERATION.

SECOND-BROOD EGGS.

Incubation period.—From two to three days after egg deposition, a semicircular red ring appears within the egg, which later disappears as the embryo attains further growth. Commonly this condition of the egg is referred to as the "red-ring" stage. A black spot appears in the egg from two to three days previous to hatching, and is caused by the dark-colored portions of the head and prothorax of the future larva which are partly visible through the eggshell. In taking observations on these features of incubation no fixed time can be given, as these changes set in and disappear gradually with the growth of the embryo or young larva. It is of value to know the significance of the "red ring" and the "black spot," as the age of the eggs can thus be approximately determined in the field.

In the cages eggs were laid daily during the entire egg-deposition period, which extended from August 6 to September 22, and a full record of the incubation period was kept during this time (Table XXVIII).

TABLE XXVIII.—*Second-brood eggs. Incubation periods of eggs laid in rearing cages.*

No. of observation.	Date.				Days.		
	Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.	Incubation.
1	Aug. 6	Aug. 8	Aug. 11	Aug. 13	2	5	7
2	Aug. 7	Aug. 9	Aug. 13	Aug. 14	2	6	7
3	Aug. 8	Aug. 10	Aug. 14	Aug. 15	2	6	6
4	Aug. 9	...do.....	Aug. 15	Aug. 16	1	6	7
5	...do....	...do....	...do....	Aug. 17	1	6	8
6	Aug. 10	Aug. 12	Aug. 16	...do....	2	6	7
7	...do....	...do....	...do....	Aug. 18	2	6	8
8	Aug. 11	Aug. 13	Aug. 18	Aug. 19	2	7	8
9	Aug. 12	Aug. 15	...do....	...do....	3	6	7
10	...do....	...do....	...do....	Aug. 20	3	6	8
11	Aug. 13	...do....	Aug. 19	Aug. 19	2	6	6
12	...do....	...do....	...do....	Aug. 20	2	6	7
13	...do....	...do....	...do....	Aug. 21	2	6	8
14	...do....	Aug. 16	...do....	Aug. 22	3	6	9
15	...do....	...do....	Aug. 20	Aug. 23	3	7	10
16	Aug. 14	Aug. 15	...do....	Aug. 21	1	6	7
17	...do....	Aug. 16	...do....	Aug. 22	2	6	8
18	...do....	...do....	...do....	Aug. 23	2	6	9
19	...do....	...do....	Aug. 21	Aug. 24	2	7	10
20	Aug. 15	Aug. 17	Aug. 22	.. do....	2	7	9
21	Aug. 16	Aug. 18	Aug. 24	Aug. 25	2	8	9
22	Aug. 17	Aug. 19	...do....	...do....	2	7	8
23	Aug. 18	Aug. 21	Aug. 25	Aug. 26	3	7	8
24	...do....	...do....	...do....	Aug. 27	3	7	9
25	Aug. 19	...do....	...do....	Aug. 26	2	6	7
26	...do....	Aug. 22	...do....	Aug. 27	3	6	8
27	Aug. 20	Aug. 23	Aug. 27	Aug. 28	3	7	8
28	...do....	...do....	...do....	Aug. 29	3	7	9
29	Aug. 21	....	Aug. 28	...do....	....	7	8
30	Aug. 22	Aug. 24	...do....	...do....	2	6	7
31	...do....	...do....	...do....	Aug. 30	2	6	8
32	Aug. 23	Aug. 25	Aug. 29	Aug. 31	2	6	8
33	Aug. 24	....	...do....	Sept. 1	....	5	8
34	...do....	....	Aug. 30	Sept. 2	....	6	9
35	Aug. 25	Aug. 27	Aug. 31	Sept. 3	2	6	9
36	...do....	...do....	...do....	Sept. 4	2	6	10
37	Aug. 26	...do....	...do....	Sept. 3	1	5	8
38	...do....	...do....	...do....	Sept. 4	1	5	9
39	...do....	...do....	Sept. 1	Sept. 5	1	6	10
40	Aug. 27	Aug. 29	....	Sept. 4	2	....	8
41	...do....	...do....	....	Sept. 5	2	....	9
42	Aug. 28	Aug. 30	Sept. 8	Sept. 9	2	11	12
43	...do....	...do....	...do....	Sept. 10	2	11	13
44	...do....	Aug. 31	Sept. 9	Sept. 11	3	12	14
45	Aug. 29	...do....	...do....	...do....	2	11	13
46	...do....	...do....	...do....	Sept. 12	2	11	14
47	...do....	...do....	Sept. 10	Sept. 13	2	12	15
48	...do....	Sept. 1	...do....	Sept. 14	3	12	16
49	Aug. 30	Sept. 3	Sept. 11	Sept. 12	4	12	13
50	...do....	...do....	...do....	Sept. 13	4	12	14
51	Aug. 31	...do....	...do....	...do....	3	11	13
52	...do....	...do....	Sept. 12	Sept. 14	3	12	14
53	...do....	...do....	...do....	Sept. 15	3	12	15
54	Sept. 1	Sept. 4	...do....	Sept. 13	3	11	12
55	...do....	...do....	...do....	Sept. 14	3	11	13
56	Sept. 2	Sept. 5	Sept. 13	...do....	3	11	12
57	Sept. 3	...do....	...do....	...do....	2	10	11
58	...do....	...do....	...do....	Sept. 15	2	10	12
59	Sept. 4	Sept. 6	Sept. 14	...do....	2	10	11
60	Sept. 5	Sept. 8	...do....	...do....	3	9	10
61	Sept. 6	Sept. 10	...do....	...do....	4	8	9
62	Sept. 7	...do....	...do....	...do....	3	7	8
63	...do....	...do....	...do....	Sept. 16	3	7	9
64	Sept. 8	Sept. 11	Sept. 15	...do....	3	7	8
65	...do....	...do....	...do....	Sept. 17	3	7	9
66	...do....	...do....	Sept. 16	Sept. 18	3	8	10
67	Sept. 9	Sept. 12	...do....	Sept. 17	3	7	8
68	...do....	...do....	...do....	Sept. 18	3	7	9
69	...do....	...do....	Sept. 17	Sept. 19	3	8	10
70	Sept. 10	Sept. 13	Sept. 16	Sept. 17	3	6	7
71	Sept. 11	Sept. 14	Sept. 17	Sept. 18	3	6	7
72	...do....	...do....	...do....	Sept. 19	3	6	8
73	...do....	...do....	Sept. 18	Sept. 20	3	7	9
74	Sept. 12	...do....	Sept. 19	Sept. 21	2	7	9
75	Sept. 15	....	....	....	....	....	....
76	Sept. 18	....	....	....	....	....	....
77	Sept. 21	....	....	....	....	....	....
78	Sept. 22	....	....	....	....	....	....

The incubation period ranged from 6 to 16 days, with an average of 9.47. In the time of appearance of the red ring, the range varied from 1 to 4 days, with an average of 2.4 days. The black spot appeared on an average 7.66 days after egg deposition, and hatching generally took place from 1 to 2 days after the black spot had been observed. (Tables XXIX and XXX.)

TABLE XXIX.—*Incubation periods of second-brood eggs. Summary of Table XXVIII.*

Appearance of red ring.		Appearance of black spot.		Total incubation period.	
Number of days.	Number of observations.	Number of days.	Number of observations.	Number of days.	Number of observations.
1	6	5	4	6	1
2	32	6	26	7	12
3	30	7	19	8	20
4	3	8	4	9	16
		9	1	10	7
		10	3	11	2
		11	8	12	4
		12	7	13	5
				14	4
				15	2
				16	1

TABLE XXX.—*Incubation periods of second-brood eggs. Summary of Tables XXVIII and XXIX.*

Observations.	Number of days—		
	For appearance of red ring.	For appearance of black spot.	For incubation.
Average	2.4	7.66	9.47
Maximum	4	12	16
Minimum	1	5	6

Eggs deposited from September 15 to September 22, inclusive, failed to hatch because of prevailing cold weather.

SECOND-BROOD LARVÆ.

Time of hatching.—The extent of the hatching period of second-brood larvæ can be accurately determined, since eggs were obtained August 6 from the earliest emerging moths and subsequently almost daily until September 22. In the cages the first larvæ hatched August 13 and the last September 21; late-deposited eggs, as already stated, failed to develop because of cold weather, which limited the number of the second-brood larvæ considerably.

Feeding period.—From a number of larvæ that hatched in the cages, 100, as given in Table XXXI, developed about normally and entered hibernation.

TABLE XXXI.—*Larvæ of second brood. Periods of feeding of larvæ in rearing cages.*

No. of larvæ.	Date of—		Days of feeding.	No. of larvæ.	Date of—		Days of feeding.	No. of larvæ.	Date of—		Days of feeding.
	Hatching.	Leaving the fruit.			Hatching.	Leaving the fruit.			Hatching.	Leaving the fruit.	
1	Aug. 13	Sept. 11	29	36	Aug. 19	Sept. 29	41	71	Aug. 27	Oct. 4	38
2	...do....	...do....	29	37	...do....	Oct. 8	50	72	...do....	Oct. 7	41
3	...do....	Sept. 12	30	38	...do....	Oct. 22	64	73	...do....	Oct. 8	42
4	Aug. 14	...do....	29	39	...do....	...do....	64	74	...do....	Nov. 1	66
5	...do....	Sept. 17	34	40	Aug. 20	Oct. 3	44	75	Aug. 28	Oct. 4	37
6	...do....	...do....	34	41	...do....	Oct. 10	51	76	...do....	Oct. 10	43
7	...do....	...do....	34	42	Aug. 21	Sept. 19	29	77	Aug. 29	...do....	42
8	Aug. 15	Sept. 12	28	43	...do....	...do....	29	78	...do....	Nov. 1	64
9	...do....	Sept. 13	29	44	...do....	Sept. 20	30	79	Aug. 30	Oct. 9	40
10	...do....	Sept. 16	32	45	...do....	...do....	30	80	Aug. 31	Sept. 26	[a] 26
11	...do....	...do....	32	46	...do....	Sept. 23	33	81	...do....	Oct. 7	37
12	...do....	...do....	32	47	...do....	Oct. 9	49	82	...do....	Oct. 8	38
13	...do....	Sept. 17	33	48	...do....	Oct. 26	66	83	...do....	Oct. 26	56
14	...do....	...do....	33	49	Aug. 22	Sept. 17	26	84	Sept. 2	Oct. 5	33
15	...do....	Sept. 21	37	50	...do....	Sept. 19	28	85	...do....	Oct. 11	39
16	...do....	Sept. 24	40	51	...do....	Sept. 28	37	86	...do....	Nov. 2	61
17	...do....	Oct. 2	48	52	...do....	Sept. 29	38	87	...do....	Nov. 12	71
18	...do....	Oct. 8	54	53	Aug. 24	Oct. 1	40	88	Sept. 3	Oct. 1	[a] 28
19	Aug. 16	Sept. 15	30	54	...do....	Sept. 28	35	89	...do....	Nov. 2	60
20	...do....	Sept. 17	32	55	...do....	Oct. 9	46	90	...do....	...do....	60
21	...do....	...do....	32	56	...do....	Oct. 23	60	91	...do....	Nov. 4	62
22	...do....	Sept. 18	33	57	Aug. 25	Sept. 22	28	92	...do....	Nov. 8	66
23	...do....	...do....	33	58	...do....	...do....	28	93	...do....	Oct. 15	73
24	...do....	...do....	33	59	...do....	Sept. 28	28	94	Sept. 4	Sept. 29	[a] 25
25	...do....	Sept. 19	34	60	...do....	...do....	28	95	...do....	Oct. 3	29
26	...do....	Sept. 23	38	61	...do....	Sept. 21	27	96	...do....	Oct. 9	35
27	...do....	Sept. 26	41	62	...do....	Sept. 28	34	97	...do....	Oct. 12	38
28	...do....	...do....	41	63	...do....	Oct. 1	37	98	...do....	Oct. 15	41
29	...do....	Sept. 29	44	64	...do....	Nov. 1	60	99	...do....	Nov. 13	70
30	Aug. 17	Sept. 16	30	65	Aug. 26	Sept. 26	31	100	Sept. 5	Oct. 26	51
31	...do....	Sept. 18	32	66	...do....	Oct. 8	43	101	Sept. 10	Nov. 15	66
32	...do....	Sept. 22	36	67	...do....	Oct. 9	44				
33	Aug. 19	Sept. 17	29	68	...do....	Oct. 11	46				1,254
34	...do....	...do....	29	69	...do....	...do....	46				
35	...do....	Sept. 19	31	70	Aug. 27	Oct. 4	38				

[a] Probably from infested apple.

TABLE XXXII.—*Feeding periods of larvæ of the second brood. Summary of Table XXXI.*

Observations.	Feeding periods.
	Days.
Average....................	39.5
Maximum....................	73
Minimum....................	26

The feeding periods for these larvæ ranged from 26 to 73 days, with an average of 39.5 days. The feeding periods in the above records are strikingly longer than those obtained for larvæ of the first brood. This is probably due to lower temperature, which during the middle of October for 7 days brought the activities of insects to an apparent standstill.

Time of leaving the fruit for wintering.—In the cages, the first larvæ left the fruit September 11, and since these were from the earliest eggs of the first moths, these records must be approximately accurate. The length of feeding for the early larvæ of the second brood was 29 to 30 days; the larvæ hatched August 13, wintering September 11. With these established facts it is thus possible to separate the first-brood and second-brood larvæ from the banded trees, which as to time of reaching maturity overlapped considerably. (See fig. 21.) In the fall, during the alternating warm and cold days, larvæ appeared under the bands in variable numbers, as recorded in Table XXXIII. The bands were last examined November 13, when 9 larvæ were collected. In the rearing cages the last larvæ emerged November 15.

Immature larvæ at hibernation time.—It is evident from both field and rearing observations that during the latter part of November, when the temperature had already reached 20° F., quite a number of larvæ had not yet attained maturity. Of the reared larvæ that hatched September 12 several which were only one-third to one-half grown remained in the fruit, while others hatching September 21 were only one-fifth to one-sixth grown.

From the bands several undersized larvæ were collected late in the fall, and it will be of interest to know whether or not they are in condition to transform the coming spring. With the records in hand it is not possible to give the relative number of immature larvæ in the field that failed to enter hibernation places. In the cages, of 133 reared larvæ 32 remained in the fruit in the fall, and judging from their size it is doubtful if any of them could possibly attain maturity that late in the season.

BAND RECORDS OF 1909.

Through the courtesy of Mr. C. E. Luke, of North East, Pa., an apple orchard of 50 trees was obtained, which was particularly well suited for band records. The trees were about 25 years old and, to the owner's knowledge, had never been sprayed and for some time past had received no care. For several years no fruit had been gathered from the orchard. It is thus evident that for years the codling moth had developed without interference and existed under natural conditions. In 1909 most of the trees carried a heavy crop of fruit.

After the loose bark had been scraped from the trunks of 16 trees, burlap bands were placed around the main trunk in the usual manner about 3 feet from the ground. On 5 of the trees bands were also placed on the main branches, so as to obtain records as to the relative number of larvæ ascending the trees from the ground from wind-fallen fruit, as compared with the number of larvæ descending from fruit on the trees. The trees, with one exception, consisted of winter varieties, 10 of which were Golden Russet, 1 Northern Spy, 2 Greening, and 3 undetermined. Since only 16 trees of the whole orchard were banded, it is believed that the comparatively small number of first-

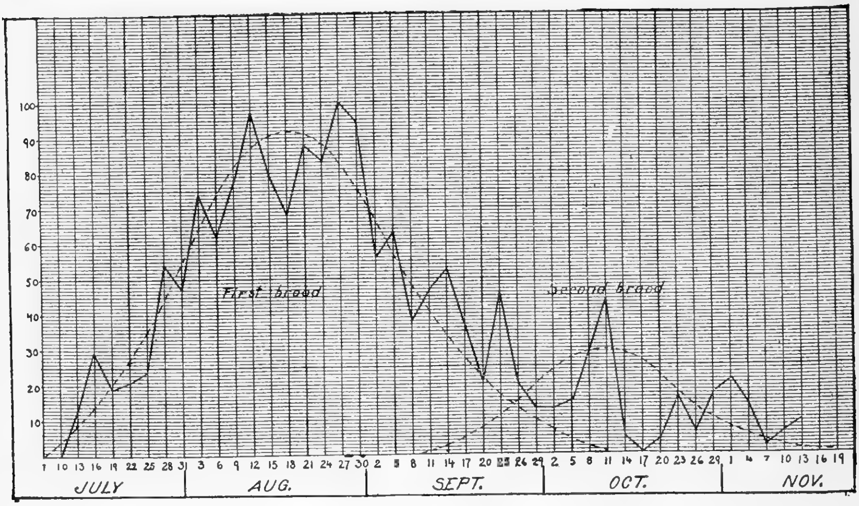

FIG. 21.—Band-record curve of 1909, at North East, Pa. (Original.)

brood larvæ which were removed had no influence upon the number of larvæ of the second brood. With the appearance of the first larvæ, July 13, the banded trees were examined every three days throughout the season until November 13. (See fig. 21.)

In comparing the number of larvæ collected from the upper and the lower bands, it will be noted (Table XXXIII) that 53 per cent were taken from the lower bands and 47 per cent from the upper bands. These figures are of interest as bearing on the effectiveness of gathering windfalls. A summary of the band records is given in Table XXXIV.

TABLE XXXIII.—*Records of larvæ collected from banded trees during 1909.*

No. of record.	Date of collecting.	Number of larvæ.			Dead or parasitized.	Number of transforming larvæ (1909).	Number of wintering larvæ.
		Upper bands (5 trees).	Lower bands (5 trees).	Total (16 trees).			
1	July 13	....	....	13	6	7	....
2	July 16	3	2	29	11	18	....
3	July 19	4	5	19	1	16	2
4	July 22	6	2	21	1	20	....
5	July 25	8	3	24	1	18	5
6	July 28	11	7	54	2	30	22
7	July 31	10	14	48	2	23	23
8	Aug. 3	22	17	74	....	51	23
9	Aug. 6	24	10	62	....	30	32
10	Aug. 9	23	15	77	....	40	37
11	Aug. 12	23	22	97	....	45	52
12	Aug. 15	15	18	79	....	3	76
13	Aug. 18	13	19	68	....	....	68
14	Aug. 21	8	30	88	....	....	88
15	Aug. 24	13	19	83	....	....	83
16	Aug. 27	18	26	100	1	....	99
17	Aug. 30	14	24	94	....	....	94
18	Sept. 2	8	11	56	....	....	56
19	Sept. 5	6	15	64	....	....	64
20	Sept. 8	7	10	38	....	....	38
21	Sept. 11	7	9	47	....	....	47
22	Sept. 14	9	7	53	....	....	53
23	Sept. 17	3	10	37	....	....	37
24	Sept. 20	4	5	21	....	....	21
25	Sept. 23	8	10	46	....	....	46
26	Sept. 26	3	4	20	....	....	20
27	Sept. 29	2	2	13	....	....	13
28	Oct. 2	4	3	13	....	....	13
29	Oct. 5	5	3	15	....	....	15
30	Oct. 8	7	6	29	....	....	29
31	Oct. 11	9	12	44	....	....	44
32	Oct. 14	1	1	5	....	....	5
33	Oct. 17	....	....	....	....	....	....
34	Oct. 20	1	1	4	....	....	4
35	Oct. 23	5	1	16	....	....	16
36	Oct. 26	2	1	6	....	....	6
37	Oct. 29	3	2	17	....	....	17
38	Nov. 1	6	8	26	....	....	26
39	Nov. 4	9	3	14	....	....	14
40	Nov. 7	....	1	2	....	....	2
41	Nov. 10	....	3	6	....	....	6
42	Nov. 13	2	5	9	....	....	9
		324	366	1,631	25	301	1,305

TABLE XXXIV.—*Records of larvæ collected from banded trees during 1909. Summary of Table XXXIII.*

Larvæ from band collections.	Percentage.
Larvæ from upper bands	46.95
Larvæ from lower bands	53.04
Transforming larvæ of band collections	18.74
Wintering larvæ of band collections	81.26
Relative proportion of first-brood larvæ	83.87
Relative proportion of second-brood larvæ	16.13
Transforming larvæ of first brood	23.46
Wintering larvæ of first brood	76.54

Few of the results here obtained have been based upon observations made during the rearing in the laboratory. For instance, the two broods of larvæ, which at the time of maturity overlap, could only be separated through rearing experiments. On comparing the two broods of larvæ it will be noted that the first brood exceeded in number the second brood about five times. Considering the number of transforming larvæ and the number of wintering larvæ of the first brood, it was found that only one-fourth of the brood completed the life cycle the same season, while three-fourths of the brood hibernated, attaining their full development with individuals of the second brood.

REVIEW OF THE LIFE-HISTORY WORK OF 1909.

During 1909 an attempt was made to rear the codling moth throughout the season, and to determine the time and relative occurrence of the different stages of the two broods. The essential results of observations for the season are shown in the diagram (fig. 22). The moths in the spring commenced to emerge June 11, reaching a maximum of emergence June 24. Moths of the following brood—the first-brood moths—appeared from August 2 to September 3, with a maximum August 26. Oviposition generally took place the fifth day after the emergence of the moths of either brood. The time during which the first brood larvæ attained maturity extended from July 10 to the end of September. Only one-fourth of the larvæ of this brood transformed and completed the life cycle the same year, while three-fourths of the larvæ hibernated. Of the second brood, mature larvæ appeared first on September 11 and continued to appear until the middle of November, at which time quite a number was prevented from further growth and failed to enter hibernation places because of prevailing low temperature. Judging by the number of larvæ collected from the banded trees, individuals of the first generation exceeded in number the second generation five times.

SEASONAL-HISTORY STUDIES OF 1907 AND 1908.

SOURCE OF REARING MATERIAL.

The rearing material for the spring of 1907 was collected from a cider bin May 9, before any larvæ had transformed. Later in the season larvæ were obtained from banded apple trees, which were then used partly the same year and partly (overwintering larvæ) for emergence records of moths the following spring. Additional band material was obtained in 1908, which, together with a small number of reared larvæ, constituted the entire supply used that year.

The rearing work for the two seasons of 1907 and 1908 was carried out on an open porch of the laboratory building, or out of doors under trees in the laboratory yard, and it is thus believed that the records of observations represent the normal transformation of the insect in orchards.

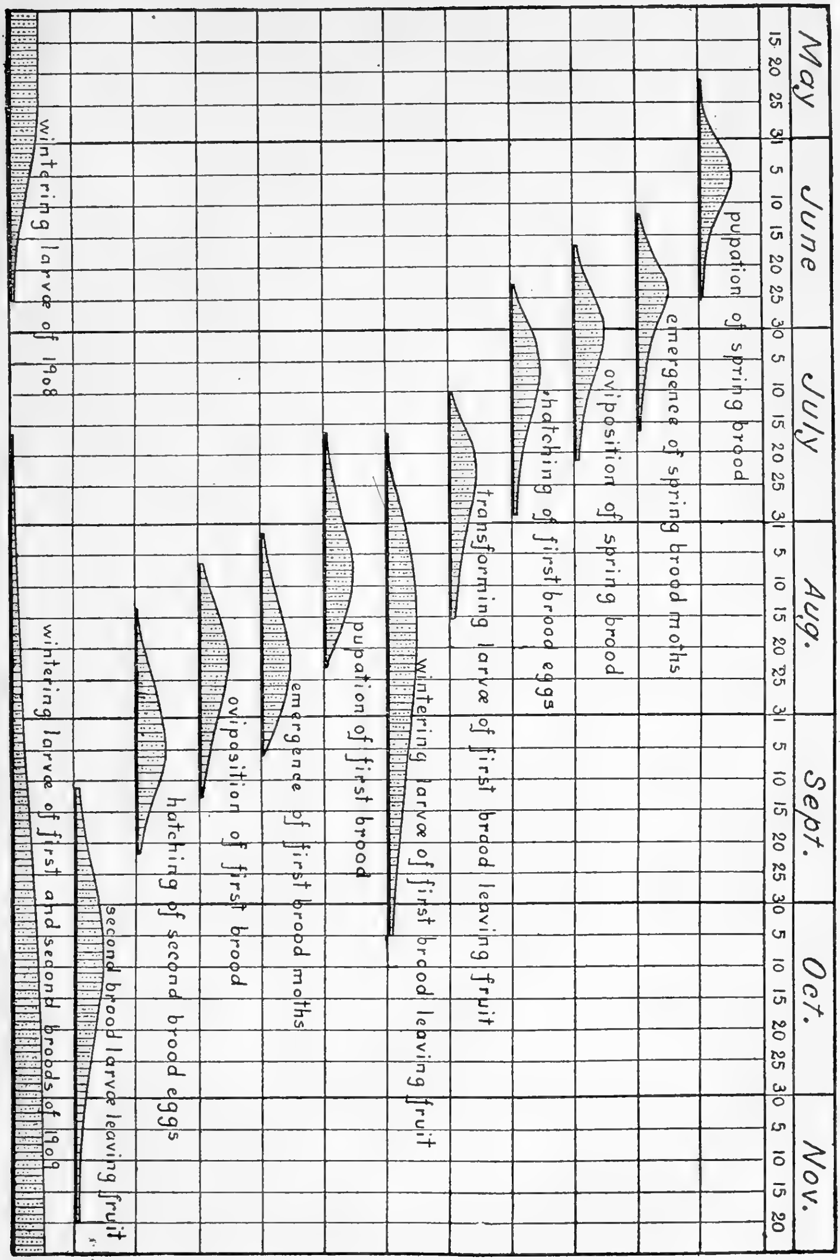

FIG. 22.—Seasonal history of the codling moth (*Carpocapsa pomonella*) as observed during 1909, at North East, Pa. (Original.)

TIME OF EMERGENCE OF MOTHS OF THE SPRING BROOD.

The first moth observed in 1907 appeared in the cages June 17 and the last July 10. The emergence period, as shown in figure 23, lasted twenty-three days, reaching a maximum on June 24. These emergence records are given in Table XXXV.

TABLE XXXV.—*Emergence of spring moths during 1907, from material collected in a cider bin.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
June 17	1	June 23	14	June 28	10	July 5	4
June 18	4	June 24	27	June 29	6	July 6	4
June 20	2	June 25	14	July 1	1	July 10	2
June 21	3	June 26	15	July 2	6		
June 22	6	June 27	3	July 3	2		124

In the spring of 1908 moths commenced to appear in the cages by May 30. The last moth of this brood emerged June 24. Unfortunately no record as to the number of emerging moths was kept, and their relative abundance can thus only be estimated. Judging by the size of a number of larvæ collected in an orchard June 10, it was evident that moths in the field must have appeared even earlier than those emerging in the cages and, on considering the band records also, it is probable that the emergence extended to the end of June.

TIME OF EMERGENCE OF MOTHS OF THE FIRST BROOD.

In 1907 the first moth emerged August 6, the maximum number emerged August 13, while the last moth appeared September 5; the emergence period was thus limited to thirty days. (See Table XXXVI and fig. 24.)

TABLE XXXVI.—*Emergence of first-brood moths during 1907. From band-collected material of 1907 and reared specimens.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
Aug. 6	1	Aug. 15	1	Aug. 21	5	Aug. 27	2
Aug. 8	2	Aug. 16	5	Aug. 22	4	Aug. 30	2
Aug. 9	1	Aug. 17	5	Aug. 23	2	Aug. 31	1
Aug. 10	5	Aug. 18	4	Aug. 24	4	Sept. 5	1
Aug. 12	5	Aug. 19	2	Aug. 25	4		
Aug. 13	18	Aug. 20	5	Aug. 26	1		80

During 1908 the emergence period was remarkably extended. In the cages the first moth emerged July 28, and the last moth emerged September 9, covering a period of forty-four days. In Table XXXVII are given the dates of emergence of the first-brood moths from band-collected material. (See also fig. 25.)

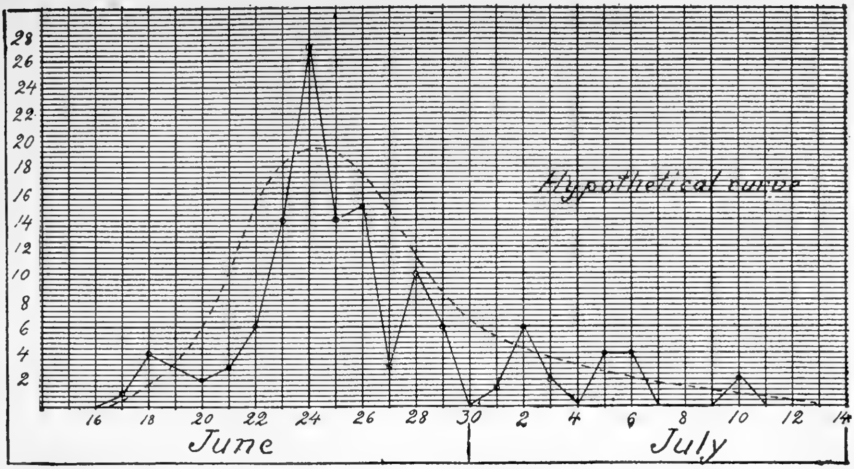

FIG. 23.—Emergence curve of spring-brood moths in 1907, at North East, Pa. Records of Mr. P. R. Jones. (Original.)

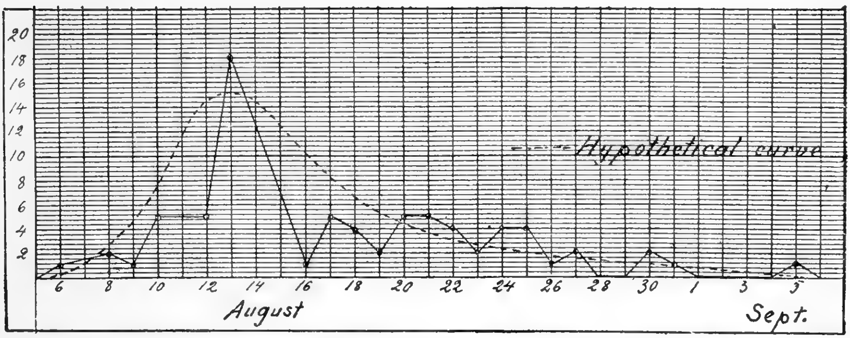

FIG. 24.—Emergence curve of first-brood moths in 1907, at North East, Pa. Records of Mr. P. R. Jones. (Original.)

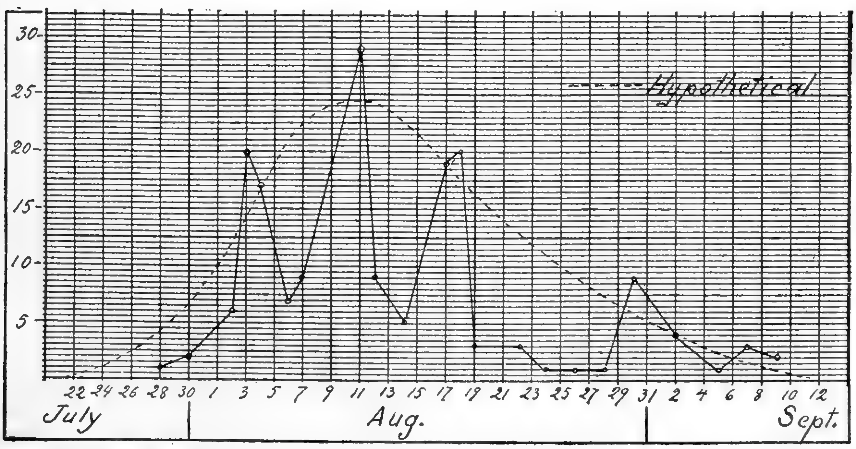

FIG. 25.—Emergence curve of first-brood moths in 1908, at North East, Pa. From band-collected material. (Original.)

TABLE XXXVII.—*Emergence of first-brood moths during 1908. From band-collected material.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
July 28	1	Aug. 7	9	Aug. 19	3	Sept. 2	4
July 31	2	Aug. 11	29	Aug. 22	3	Sept. 5	1
Aug. 2	6	Aug. 12	9	Aug. 24	1	Sept. 7	3
Aug. 3	20	Aug. 14	5	Aug. 26	1	Sept. 9	2
Aug. 4	17	Aug. 17	19	Aug. 28	1		
Aug. 6	7	Aug. 18	20	Aug. 30	9		172

BAND RECORDS OF 1907 AND 1908.

For the banding work in 1907 an unsprayed orchard was kindly placed at the disposal of the Bureau of Entomology, through the courtesy of Mr. W. Towne, of North East, Pa.

After the loose bark on the trunk and larger branches had been scraped off, 16 trees were properly banded. The banded trees were examined once a week from July 12 to November 5 for larvæ and pupæ. The results of these observations are given in Table XXXVIII.

TABLE XXXVIII.—*Band records taken from 16 apple trees during 1907.*

No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of emerging moths.	No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of emerging moths.
1	July 12	....	....	14	Sept. 21	85	....
2	July 23	....	....	15	Sept. 26	41	....
3	July 27	23	14	16	Oct. 1	25	....
4	Aug. 1	25	14	17	Oct. 6	17	....
5	Aug. 6	29	8	18	Oct. 11	9	....
6	Aug. 11	51	1	19	Oct. 16	6	....
7	Aug. 17	76	....	20	Oct. 21	10	....
8	Aug. 21	127	....	21	Oct. 26	8	....
9	Aug. 26	272	....	22	Oct. 31	9	....
10	Aug. 31	157	....	23	Nov. 5	8	....
11	Sept. 5	182	....				
12	Sept. 11	176	....			1,457	37
13	Sept. 16	121	....				

Because of the short and cool season of 1907, the great majority of the larvæ of the first brood wintered, which resulted further in a very small second generation. It is evident from figure 26 that the second-brood larvæ constituted only a small fraction of the total band collection. Since the two broods of larvæ evidently always overlap, the relative number for each brood can only be approximately estimated. Judging by the first emergence of moths of the first brood and by other rearing records of the year, the first larvæ of the second brood reached maturity about October 10. Judging by this the entire band collection would consist of 96.5 per cent of first-brood larvæ and 3.5 per cent of second-brood larvæ. Considering, further, that out of the 1,400 larvæ of the first brood only 37 individuals transformed, while the rest wintered, it can be figured approximately that only 3 per cent of the first-brood larvæ transformed, while 97 per cent wintered.

In 1908 the band-record experiments were carried out at Westfield, N. Y., in an unsprayed orchard consisting of large apple trees belonging to Mr. George Walker and kindly placed at the disposal of the Bureau of Entomology. The bands were examined once a week, and

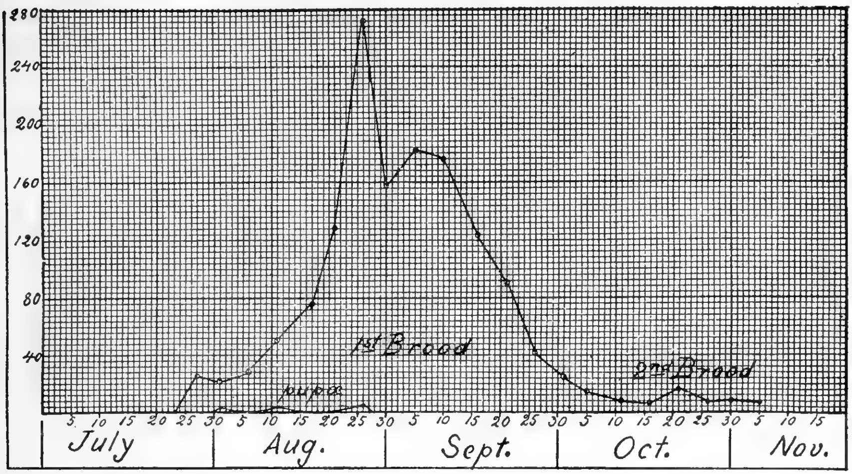

FIG. 26.—Band-record curve of 1907, at North East, Pa. (Original.)

the larvæ were counted and removed to the laboratory for further observations. As is evident from figure 27, the bands were placed on the trees about one week too late, so that no record was obtained of the earliest maturing larvæ. The two broods are here clearly dis-

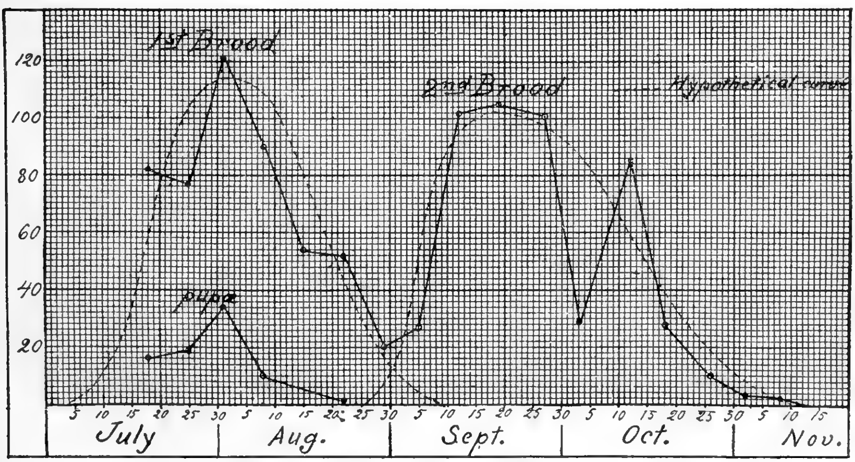

FIG. 27.—Band-record curves of 1908, at Westfield, N. Y. (Original.)

tinguishable, overlapping but slightly at the end of August. The great drop in the number of larvæ in early October (fig. 27) was due to cold weather. In Table XXXIX is given the full record of the band collections for 1908, with a summary in Table XL.

Table XXXIX.—*Band records taken from ten apple trees during 1908.*

No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of emerging moths.	
			1908.	1909.
1	July 18	84	66	1
2	July 25	77	69	1
3	Aug. 1	121	87	13
4	Aug. 8	90	25	27
5	Aug. 14	54	4	33
6	Aug. 22	52	1	38
7	Aug. 29	20	....	14
8	Sept. 5	27	....	25
9	Sept. 12	102	....	43
10	Sept. 19	105	....	92
11	Sept. 27	101	....	56
12	Oct. 3	29	....	26
13	Oct. 12	85	....	50
14	Oct. 18	28	....	20
15	Oct. 26	10	....	7
16	Nov. 2	6	....	2
17	Nov. 9	2	....	1
		993	252	449

Table XL.—*Band records of 1908. Summary of Table XXXIX.*

Larvæ from band collections.	Percentage.
Transforming larvæ of band collections	35.9
Wintering larvæ of band collections	64.1
Relative proportion of first-brood larvæ	50
Relative proportion of second-brood larvæ	50
Transforming larvæ of first brood	67.7
Wintering larvæ of first brood	32.3
Parasitized, injured, and dead larvæ	30.1

WEATHER RECORDS FOR 1907, 1908, AND 1909.

During the three seasons that the life history of the codling moth has been studied in northwestern Pennsylvania (1907–1909) daily records have been kept of the maximum and minimum temperatures, together with other climatic conditions. In preparing the temperature curves shown in figures 28–30 use has also been made of the weather records of the Weather Bureau made at Erie, Pa.

The climatic conditions have been strikingly different during the three seasons. The year 1907 was marked by an abnormally low temperature, a late spring, and an early fall with a rather high precipitation for the summer months. The month of May was the coldest on record during a period of eighteen years. In 1908, on the contrary, the spring was very early, the mean temperature was above normal, and the summer was marked by two periods of severe drought, the dry condition being especially felt during the latter part of August. In most respects 1909 was considered normal.

By comparing the daily fluctuations of temperature with the various records showing the behavior of the codling moth it will be found

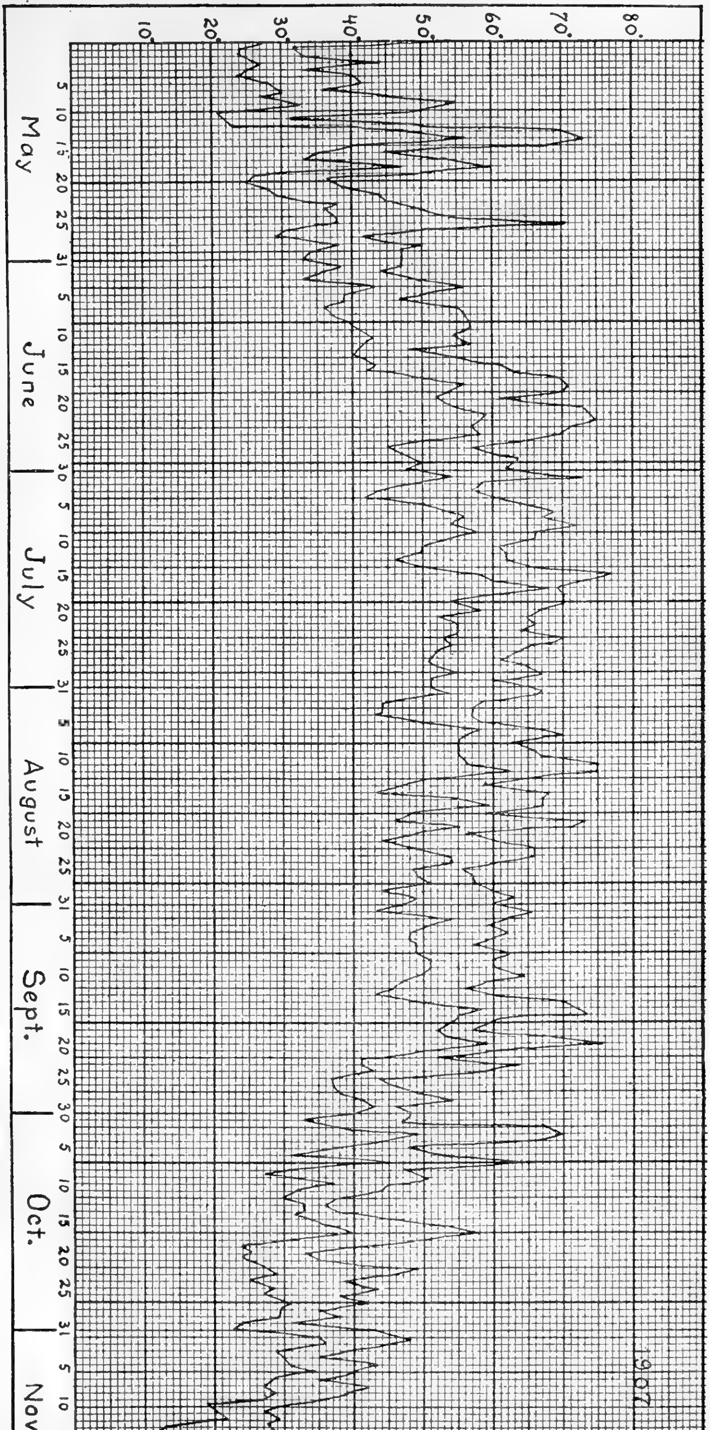

FIG. 28.—Curves showing the maximum and minimum temperature at North East, Pa., 1907. (Original.)

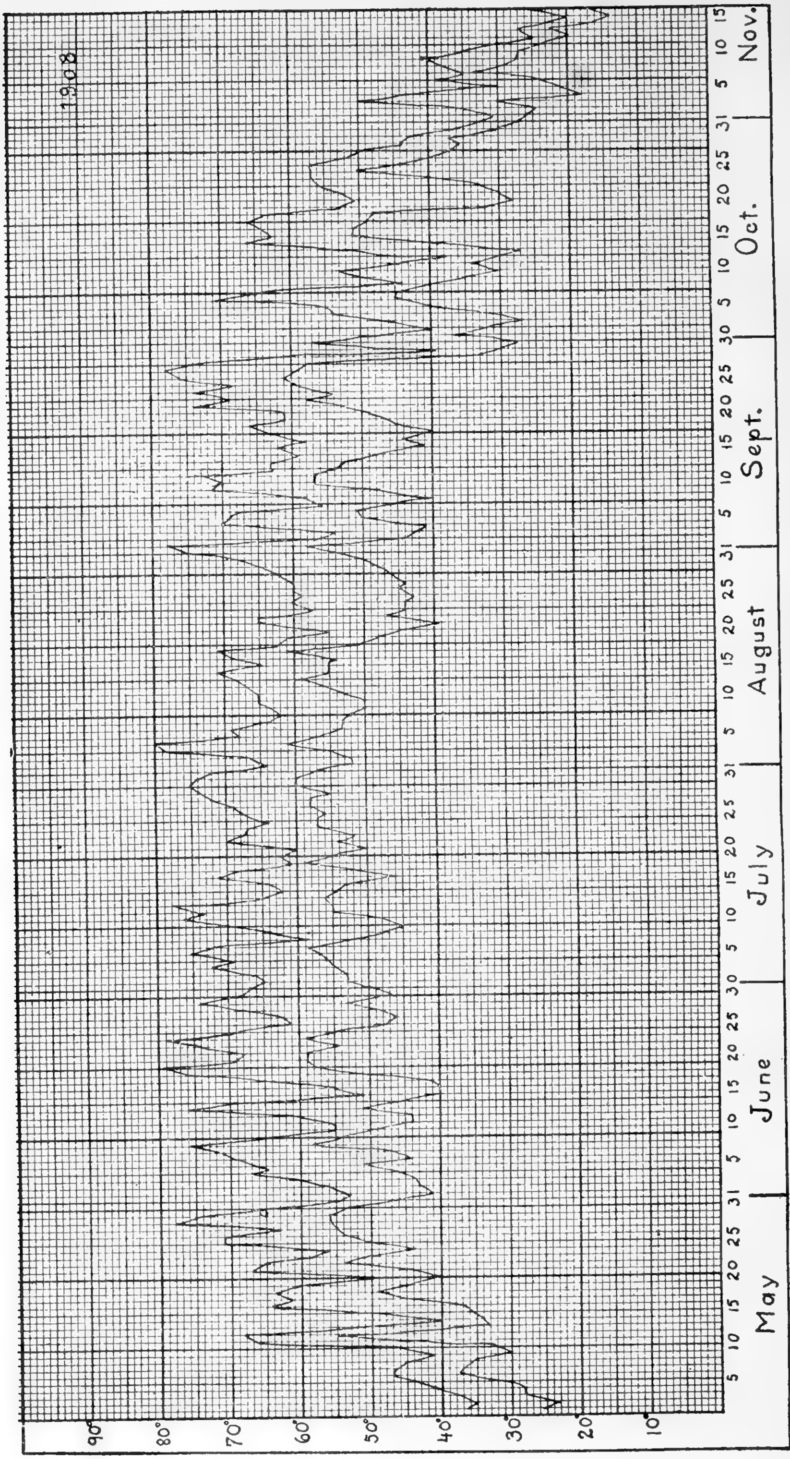

FIG. 29.—Curves showing maximum and minimum temperature at North East, Pa., 1908. (Original.)

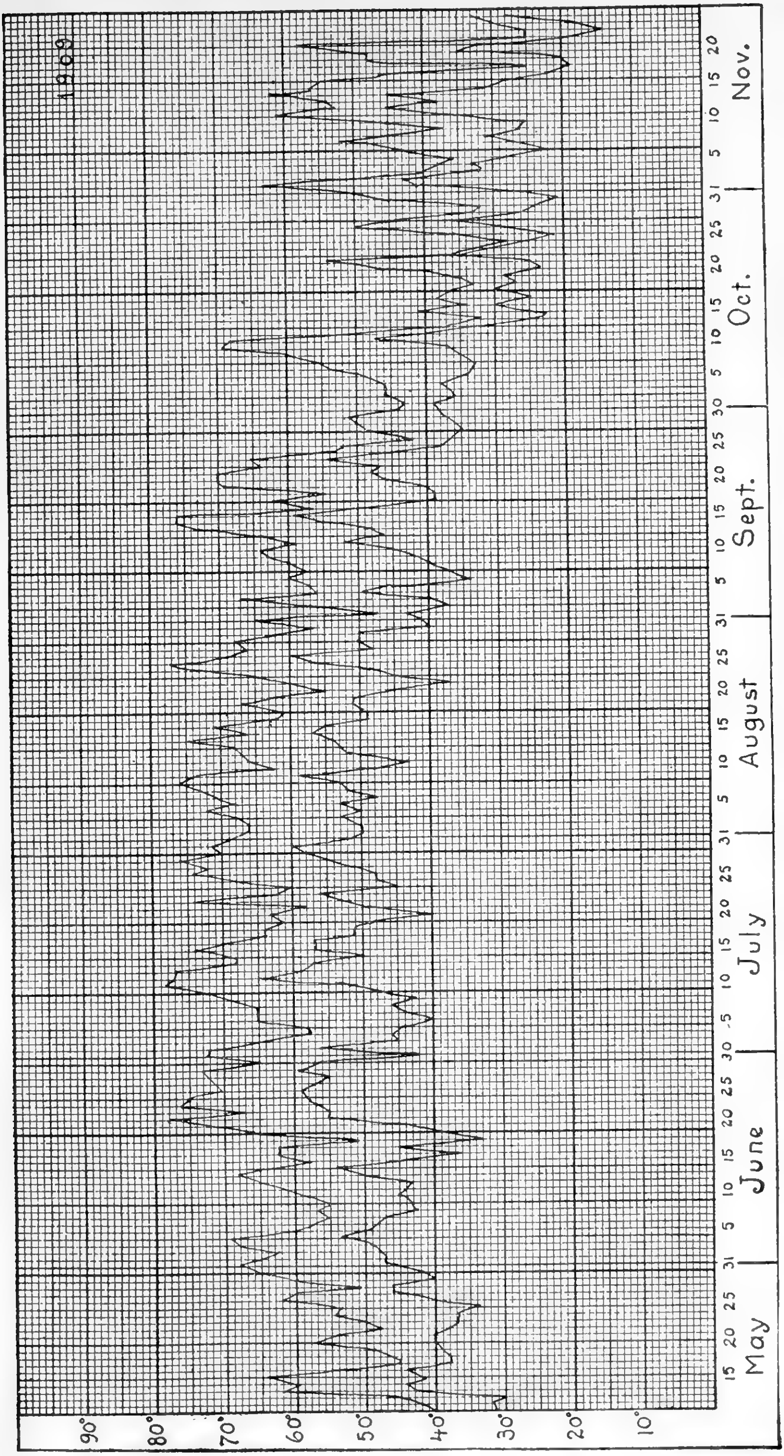

FIG. 30.—Curves showing the maximum and minimum temperature at North East, Pa., 1909. (Original.)

that its development has been greatly influenced by the temperature. A cold spell was invariably followed by a delay in transformation, while a rise in temperature produced a corresponding hastening in development.

COMPARATIVE LIFE-HISTORY STUDIES FOR THE SEASONS OF 1907, 1908, AND 1909.

On considering the records of the emergence of the moths (fig. 31) and the time of maturity and relative abundance of larvæ (fig. 32) for the three years under consideration, it is evident that the codling moth in its development is greatly influenced by seasonal conditions.

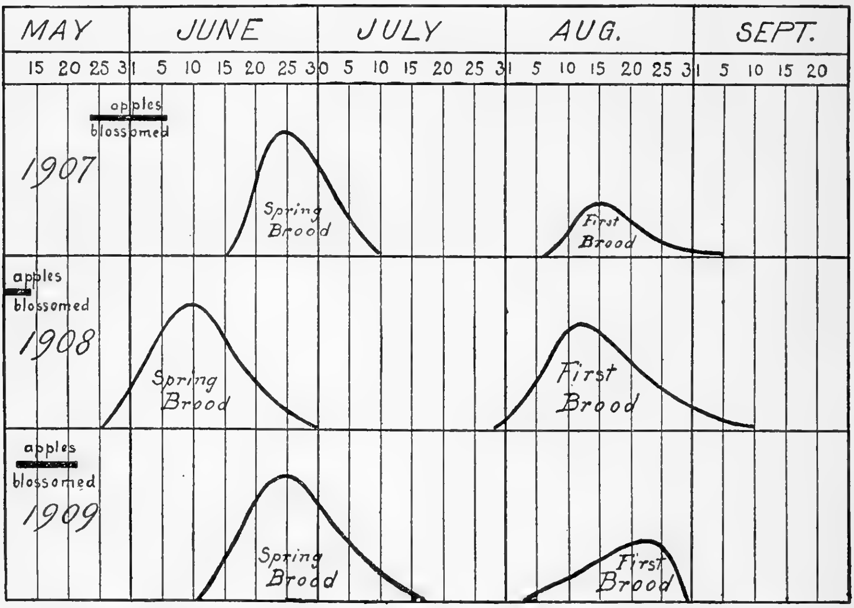

FIG. 31.—Time of emergence of spring-brood and first-brood moths, and the blossom periods of apple trees, during 1907, 1908, and 1909, at North East, Pa. (Original.)

The cold and wet spring of 1907 limited the emergence of the spring moths to a short period. The prevailing low temperature delayed the larvæ to such an extent that only 3 per cent of the first brood transformed. The entire second generation was reduced to 3.5 per cent against 96.5 per cent of the first generation.

The season of 1908 was evidently very favorable for the development of the codling moth. The early spring brought out the moths by May 25. During the long and warm summer the majority of the larvæ of the first brood transformed in great numbers (only 32.3 per cent wintered), and the following brood of larvæ attained a size equal to that of the first brood.

The development of the insect in 1909 was about intermediate as compared with the results of the previous years. The early fall was quite variable, changing frequently from warm to extremely cold, resulting in a sudden stop in the transformation of late larvæ of the first brood; the oviposition period for the second brood became limited and also late deposited eggs failed to hatch. A number of larvæ of the second brood spun up before they became full grown and several did not reach hibernating places before freezing temperature set in. Of the insects developed during 1909 83.87 per cent were of the first generation and 16.13 per cent of the second generation. Of the first-brood larvæ 23.46 per cent transformed, while 76.54 per cent

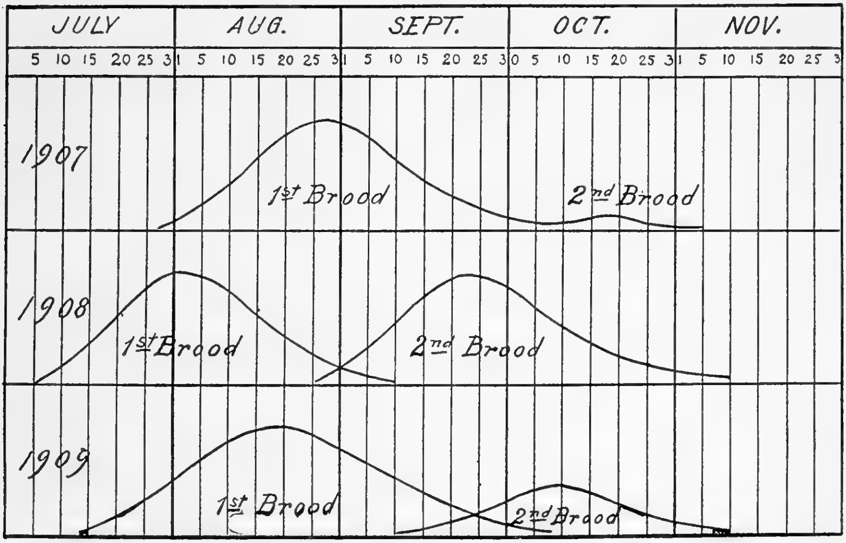

FIG. 32.—Time of leaving the fruit of the first-brood and second-brood larvæ of the codling moth, during 1907, 1908, and 1909, at North East, Pa. (Original.)

wintered. A summary of the results of life-history studies for these three years is given in Table XLI. (See also figs. 31 and 32.)

TABLE XLI.—*Summary of results of band records for 1907, 1908, and 1909, showing the comparative size of broods and relative number of transforming and wintering larvæ.*

Larvæ from band collections.	Percentages for—		
	1907.	1908.	1909.
Transforming larvæ of total band collection	2.5	35.9	18.74
Wintering larvæ of total band collection	97.5	64.1	81.26
Relative proportion of first-brood larvæ	96.5	50	83.87
Relative proportion of second-brood larvæ	3.5	50	16.13
Transforming larvæ of first brood	3	67.7	23.46
Wintering larvæ of first brood	97	32.3	76.54

INSECT ENEMIES.

The feeding habits of codling-moth larvæ within the fruit offer the insect considerable protection against both predaceous and parasitic enemies. At the time of maturity, however, when the larvæ leave the fruit and seek suitable places for transformation or hibernation, they are for a short time exposed and are sometimes attacked by various insect enemies. A small black beetle (*Tenebrioides corticalis* Melsh.) and its very slender larva were found during August to late October, 1909, under the burlap bands on apple trees. Dead and partly devoured codling-moth larvæ were frequently found attacked by both beetles and larvæ of this species. Another black beetle, *Dromius piceus* Dej., was also found quite frequently. *Platynus obsoletus* Say was taken on several occasions, and a few specimens of the larger ground beetle (*Galerita janus* Fab.) were also collected under the bands.

The following beetles were collected from banded trees, but without any observation as to their attacks upon larvæ of the codling moth: *Melanotus fissilis* Say, *Cryptarcha ampla* Er., *Mycetochares fraterna* Say, *Tenebrio tenebrioides* Beauv., and *Hymenorus* sp. These and previously named beetles were determined by Messrs. E. A. Schwarz and H. S. Barber, of the Bureau of Entomology.

The following species of ants, determined by Mr. Theo. Pergande, were found to attack the larvæ of the codling moth under the bands: *Camponotus pennsylvanicus* (Dej.) Mayr., *Formica subsericea* Say, *Cremastogaster lineolata* Say, and *Myrmica lobicornis* Nyl.

A centipede, *Geophilus rubens* Say, determined by Mr. R. V. Chamberlin, of Provo, Utah, was taken several times beneath the bands, in the act of feeding on larvæ of the codling moth.

A hymenopterous parasite (*Ascogaster carpocapsæ* Vier.), as determined by Mr. H. L. Viereck, of the Bureau of Entomology, issued in the cages from band material of the two broods of the codling moth, and proved to be quite common.

SUMMARY.

In northwestern Pennsylvania the codling moth produces in the course of a year one full generation and a partial second generation.

The life-cycle of the insect may be briefly summarized as follows: In the spring the overwintering larva pupates in early June, and three weeks later the moth emerges. The emergence extends over a period of about 1 month, beginning about the middle of June. Oviposition generally takes place 3 or 4 days after the emergence of the moth, and the egg hatches in 1 week. Eggs showing a red ring are about 3 days old, while those with a black spot in the center will mostly hatch in 1 or 2 days. Shortly after hatching the young larva enters the fruit and feeds about 26 days. On reaching maturity the larva seeks a hiding place beneath the rough bark of the trunk of the tree and constructs a cocoon within which pupation takes place about 1 week after the larva left the fruit. Some of the larvæ do not pupate at this time but winter, and the moths emerge the following spring, together with moths from second-brood larvæ. The pupal stage—called the first-brood pupæ, though the second set of pupæ of the season—lasts on an average 12 days. The emergence period of this second set of moths, called first-brood moths, begins in early August and lasts about 1 month. With the appearance of new eggs, resulting from the first-brood moths, the life-cycle of the first generation is completed, covering on an average 58 days. The second-brood eggs hatch generally within 9 days and the resulting larvæ feed about 40 days, after which they enter hibernation, making cocoons beneath the rough bark on the trunk of the trees. The life-cycle of the second generation and part of the first generation is first completed with the transformation of the insect the following spring. The period covered by the different stages of the two broods for 1909, as shown in figure 22, closely represents average conditions.

The relative number of transforming larvæ of the first brood is variable under different seasonal conditions.

The relative abundance of second-brood larvæ depends more upon seasonal conditions and food supply than upon the number of transforming larvæ of the first brood.

Larvæ of the second brood are always present in injurious numbers, so that measures should be taken to combat the second as well as the first brood.

The time of the emergence of the spring brood of the moths is variable under different seasonal conditions and depends largely upon the relative lateness of the spring.

The time of emergence of the summer brood or first brood of moths is fairly constant and generally commences about the 1st of August.

In the control of the codling moth with poison sprays three applications should be made in this section of the country. The first application should be made after the blossom period just after the petals drop, the second application from 3 to 4 weeks later, and the third application from 9 to 10 weeks after the petals drop, or about the 1st of August.

U. S. D. A., B. E. Bul. 80, Part VII (Revised). D. F. I. I., March 30, 1911.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

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Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

The so-called one-spray method of spraying for the codling moth on apples consists essentially in making the application following the dropping of the petals so thorough that it will result in the practical extermination of the first brood of larvæ, subsequent treatments, therefore, becoming unnecessary. This method of spraying has come into considerable use in the Northwest following the investigations of Dr. E. D. Ball, in Utah, and Prof. A. L. Melander, in Washington, and its applicability for the control of the codling moth under eastern conditions has been strongly urged. The subject has already received attention at the hands of several eastern entomologists, notably Gossard, in Ohio, Sanderson, in New Hampshire, Felt, in New York, and Rumsey, in West Virginia. It is not within the scope of the present paper, which is in the nature of a preliminary report, to review the present status of the one-spray method. On the whole, however, it has appeared to the writers from a study of the experiments thus far reported as bearing directly upon the control of the codling moth, that most of these have been more or less inconclusive as not having fully met the conditions stated to be essential for successful one-spray work. The indispensable requisite is stated to be the placing of necessary poison in the inner calyx cup. By referring to figure 33 the structure of the calyx end of a young apple may be noted, namely, that there are two cavities, one above and one below the stamen bars or filaments. The observations of Doctor Ball led him to believe that the great majority of codling-moth larvæ in seeking entrance at the calyx end of the apple enter through the lower

calyx cup, and would thus mostly escape destruction unless the poison had been there placed. Other investigators have shown, notably the late Professor Slingerland, that codling-moth larvæ in the East feed in the outer calyx cup, and the results which have been obtained with mist sprays in the East during the past twenty-five years, filling mostly only the outer calyx cavity, have been much more favorable than could be expected were it the rule that feeding occurs principally in the inner cup. The stamen bars, as shown in the figure, form a dome or shield over the cavity below, and the poison is best forced

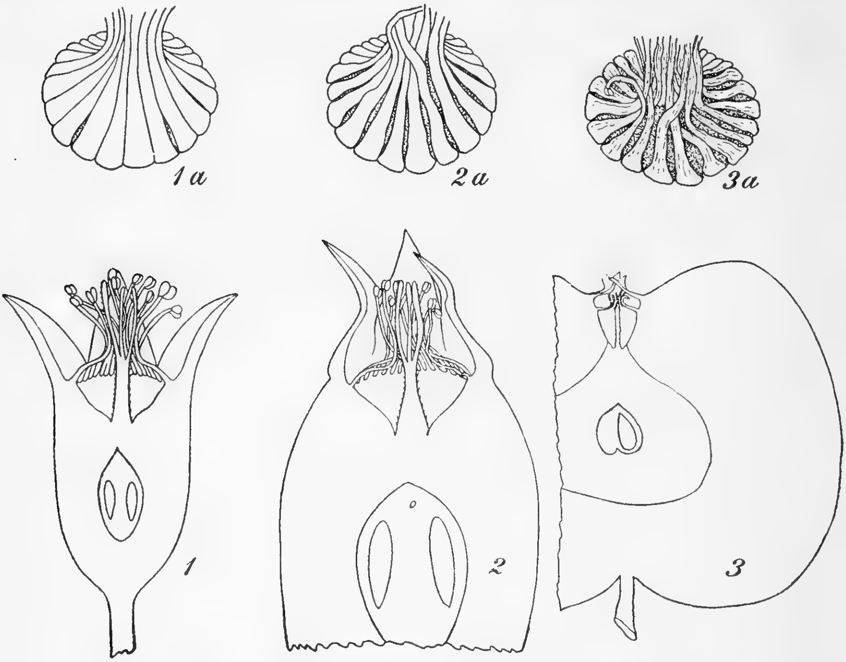

FIG. 33.—The condition of the calyx cup of the apple in relation to spraying for the codling moth: *Fig. 1.*—A calyx cup, five days after the petals fell, split open to show two cavities; *1a*, the roof of stamens as seen from above. *Fig. 2.*—A calyx cup two weeks after blossoming, showing the calyx lobes above; *2a*, the stamens from above to show spaces. *Fig. 3.*—The relation of the two cavities in a nearly grown apple; *3a*, stamens from above. (From Ball.)

through these bars by a coarse, forceful spray, as from a Bordeaux nozzle and with a pump pressure of from 175 to 200 or more pounds. It is also required that the work of spraying be done very thoroughly, the spray being directed from above into each and every fruit cluster. The use of an elbow or crook between the rod and nozzle to incline the nozzle at an angle of from 30 to 45 degrees with the spray rod permits of better directing the spray downward, and even in the case of small trees it is recommended to spray from a platform on the wagon. The employment of a coarse nozzle and a high pressure uses a large amount of spray before the trees are properly sprayed, literally drenching the trees.

This single treatment, as above described, made just after the falling of the petals, in the experience of Professor Melander has been sufficient to keep the codling moth under complete control. Doctor Ball, however, inclines to two early treatments, the second being given before the calyx lobes entirely close, as within ten days after the falling of the petals. At the time of this latter treatment the stamen bars have become more or less shriveled and more readily permit the entrance of the spray into the inner calyx cup. The two practices as recommended by Professors Ball and Melander do not differ in principle, however, and Doctor Ball's second treatment is in the nature of a supplementary one. In summing up his experiments, covering several years in Utah, Doctor Ball states his conclusions as follows:[a]

> The first early spray is the best, the second is nearly as good, and the third is of little value.
>
> Two early driving sprays will kill an average of 90 per cent of the first brood of worms.
>
> Sufficient poison is retained [in calyx cup] from the early sprayings to kill an average of 74 per cent of the second brood of worms.
>
> Two early sprayings correctly applied are worth from 6 to 16 times as much as three late ones.

Professor Melander says:[b]

> A single thorough spraying has afforded practically 100 per cent returns over hundreds and hundreds of acres of Washington orchards. The same benefit from the single spraying has also been abundantly attained in Colorado and Utah.

Aside from the particular question involved as to whether the one-spray method will sufficiently control the codling moth under eastern conditions, several other considerations must be taken into account.

In the arid valleys of the West, as in Utah, Washington, and Colorado, practically the only important insect enemy of the fruit of the apple is the codling moth, and fungous diseases are, on the whole, of but little importance. The use of fungicides is therefore not ordinarily necessary and there is thus to be controlled only the codling moth.

In the Mississippi Valley and Eastern States, however, and in central and eastern Canada, there are, in addition to the codling moth, the apple and plum curculios and the lesser apple worm, which in many sections are exceedingly injurious, the plum curculio in some parts being scarcely less in importance than the codling moth itself. Furthermore, the general prevalence of fungous diseases, such as the apple scab, apple fruit blotch, bitter rot, and leaf-spot affections, requires several fungicidal treatments during the season. Entomolo-

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[a] Bul. 67, Bur. Ent., U. S. Dept. Agr., p. 75, 1907.

[b] Journal of Economic Entomology, vol. 2, p. 67, 1909.

gists and plant pathologists have by many experiments determined a schedule of spraying with a combined arsenical insecticide and a fungicide—Bordeaux mixture or lime-sulphur wash—which affords a large degree of protection from all of these troubles. To effect the control of insects other than the codling moth and the several fungous diseases mentioned requires several applications of sprays, and renders the one-spray method of questionable practical value where these several troubles exist. These differences in fruit-growing conditions between the West and East should be borne in mind in any consideration of the practicability of the one-spray method.

RESULTS OF EXPERIMENTS WITH THE ONE-SPRAY METHOD AS COMPARED WITH RESULTS FROM THE USUAL SCHEDULE OF APPLICATIONS.

During the season of 1909 the Bureau of Entomology carried out experiments to determine the relative value, in the control of the codling moth and plum curculio under eastern conditions, of the one-spray method in comparison with a schedule of applications requiring a total of from three to five treatments according to locality, representing practically the method of spraying considered best for the localities in question. The work was carried out in three States, namely, in Virginia, in Arkansas, and in Michigan, and included four orchards, thus representing a considerable range in climatic conditions. The field work in Arkansas was under the immediate direction of Mr. E. L. Jenne, assisted by Mr. F. W. Faurot; in Virginia the field operations were under the immediate charge of Mr. E. W. Scott, assisted by Mr. L. F. Pierce, of the Bureau of Plant Industry. Mr. R. W. Braucher was charged with the spraying operations in Michigan, and was assisted a part of the time by Mr. Walter Postiff. The work relating to the control of fungous diseases in each of the orchards was done in cooperation with Mr. W. M. Scott, of the Bureau of Plant Industry. In addition to obtaining data on the effects of the treatments on the codling moth and plum curculio, in Arkansas injury by the lesser apple worm was taken into account, which in that section is very troublesome.

EXPERIMENTS IN ARKANSAS.

The experiments in Arkansas were carried out in the orchard of Mrs. S. E. Jones in the vicinity of Siloam Springs. The entire orchard, consisting of 344 trees, was divided into five plats, as shown in the accompanying diagram (fig. 34.) Trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. The orchard, a general view of which is shown in Plate X,

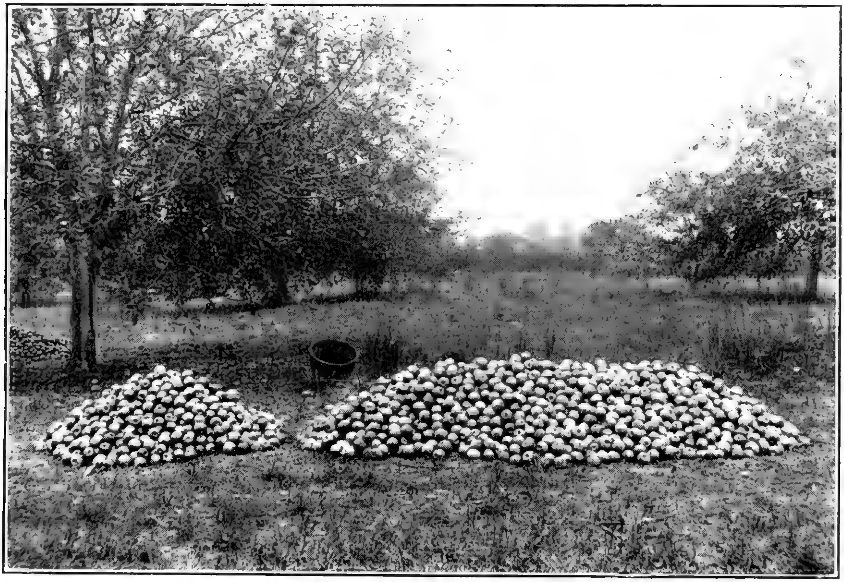

FIG. 1.—VIEW IN ORCHARD OF MRS. S. E. JONES, NEAR SILOAM SPRINGS, ARK. (ORIGINAL.)

FIG. 2.—VIEW IN ORCHARD OF MR. W. S. BALLARD, NEAR CROZET, VA. (ORIGINAL.)

figure 1, is an isolated one and the location very favorable for the work in hand. Plat I included 7 rows, Plat II a single row, Plat III 3 rows, Plat IV 5 rows, and Plat V (the unsprayed plat) included 5 rows, this last plat being at one end of the orchard. The orchard

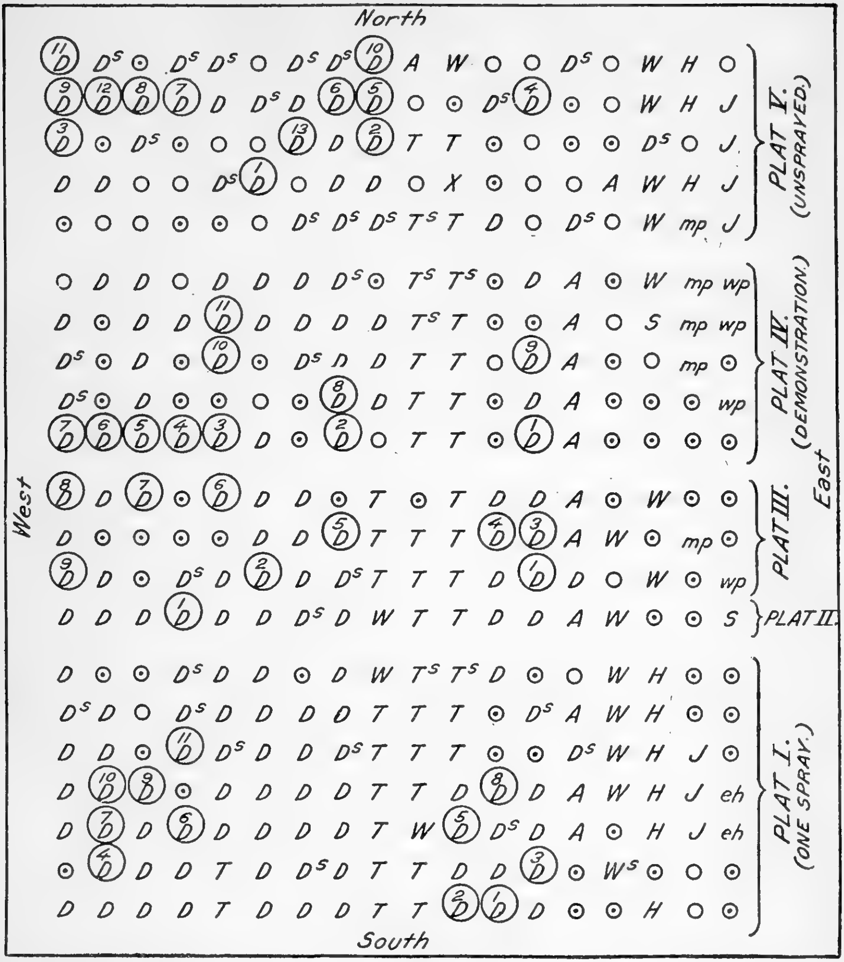

FIG. 34.—Diagram of the Mrs. S. E. Jones orchard, Siloam Springs, Ark., showing location of plats and trees used for making counts of fruit: *D*, Ben Davis variety; *A*, Arkansas Black; *T*, Mammoth Black Twig; *W*, Winesap; *J*, Jonathan; *mp*, Missouri Pippin; *wp*, White Winter Pearmain, etc. Trees of Ben Davis variety only were used for making counts of fruit. These are indicated for the respective plats by a circle, the numbers agreeing with the numbers of these trees in the tables. (Original.)

included a miscellaneous assortment of varieties, as shown by the legend under figure 34, but principally the Ben Davis, on which variety counts were made. The treatments to which the respective plats were subjected are shown in Table I.

TABLE I.—*Treatments and dates of applications of sprays for the codling moth and plum curculio. One-spray method. Siloam Springs, Ark., 1909.*

Dates of applications.	Plat I. (One-spray method.)	Plat II. (One-spray method.)
First application, April 24–25 (after falling of petals).	Drenched with arsenate of lead. 1 pound to 50 gallons of water. Bordeaux nozzles. 17 gallons per tree. 200 pounds pressure.	Drenched with arsenate of lead. 1 pound to 50 gallons Bordeaux mixture (3-3-50). Bordeaux nozzles. 17 gallons per tree. 200 pounds pressure.
Second application, May 25–26.	Bordeaux mixture only (4-4-50). Bordeaux nozzles.	Bordeaux mixture only (4-4-50). Bordeaux nozzles.
Third application, July 2.	.....do.....	Do.
Fourth application, July 22.	Unsprayed.....	Unsprayed.
Fifth application, August 10.	.....do.....	Do.

Dates of applications.	Plat III. (One-spray method.)	Plat IV. (Demonstration.)	Plat V. (Unsprayed.)
First application, April 24–25 (after falling of petals).	Drenched with arsenate of lead. 1 pound to 50 gallons of water. Vermorel nozzles. Mist spray. 8.3 gallons per tree. 200 pounds pressure.	Not drenched. Vermorel nozzles. Mist spray, arsenate of lead. 2 pounds to 50 gallons Bordeaux mixture (3-3-50). 11 gallons per tree. 200 pounds pressure.	Unsprayed.
Second application, May 25–26.	Bordeaux mixture only (4-4-50). Mist spray. Vermorel nozzles.	Bordeaux mixture (4-4-50) with 2 pounds arsenate of lead. Mist spray. Vermorel nozzles.	Do.
Third application, July 2.	.....do.....	Bordeaux mixture (4-4-50) with 2 pounds arsenate of lead. Mist spray. Vermorel nozzles.	Bordeaux mixture only (4-4-50).
Fourth application, July 22.	Unsprayed.....	.....do.....	Unsprayed.
Fifth application, August 10.	.....do.....	.....do.....	Do.

Plats I, II, and III received an arsenical treatment of 1 pound of arsenate of lead to 50 gallons of water immediately after the falling of the petals. Two subsequent applications of Bordeaux mixture only were made to protect the fruit from the apple blotch and bitter rot and one Bordeaux treatment was also given to the check plat (Plat V) for the same purpose, as these affections in this locality are exceedingly troublesome and otherwise would have interfered greatly with results. Plat IV, which received demonstration treatment, received five applications in all, as shown, of a combined spray of Bordeaux mixture and arsenate of lead, the latter being used at the rate of 2 pounds to 50 gallons of spray. On the demonstration plat the usual eddy chamber, or Vermorel nozzle, was used and while an effort was made to spray thoroughly according to usual recommendations in the East, the drenching of the trees was carefully avoided. Plat I, which received the one-spray treatment proper, was very thoroughly treated and required an average of 17 gallons per tree. The Bordeaux nozzle was used with a crook between the nozzle and spray rod and a pressure was maintained at about 200 pounds. Plat II received exactly the same treatment except that arsenate of lead was applied in dilute Bordeaux mixture to determine

to what extent russeting of the fruit might result from so liberal a use of the fungicide. The treatment for Plat III was identical with that for Plat I, except that Vermorel nozzles were used. It was desired to determine the comparative merits of a mist spray as against a coarse spray, and it will be noted that the quantity of liquids required per tree for the mist spray (Plat III) was somewhat less than one-half the amount necessary in the drenching work (Plat I).

The results presented include all of the drop fruit throughout the season and the fruit from the trees at picking time in the fall. All apples were carefully examined as to worminess from the codling moth and as to injury by the plum curculio and lesser apple worm. Fruit from Plats I and III was badly injured by the apple blotch, which can be accounted for only by the omission of Bordeaux mixture from the treatment given immediately after the falling of the petals. Fruit from Plat II, which had been thoroughly drenched with Bordeaux mixture using Bordeaux nozzles, was not noticeably more russeted than in the case of fruit from the demonstration plat and was free from apple blotch. Plat IV showed some infection from scab owing to the fact that it had not been sprayed with Bordeaux mixture before the blossoms opened.

THE CODLING MOTH.

In Table II are shown results of treatments of Plats I, III, IV, and V as to injury from the codling moth. Plat II is not here considered nor subsequently, as the point involved, namely, the effect on the fruit of a drenching spray of arsenate of lead and Bordeaux mixture after the falling of the petals, has already been indicated. There was not noticeably more russeting of the fruit on Plat II than on Plat IV which received the demonstration treatment.

TABLE II.—*Sound and wormy apples from one-spray, demonstration, and unsprayed plats. Siloam Springs, Ark., 1909.*

PLAT I. ONE SPRAY (BORDEAUX NOZZLES).

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	703	522	419	118	181	222	286	315
Sound	4,986	4,291	3,377	2,632	3,265	3,540	3,021	5,128
Total	5,689	4,813	3,796	2,750	3,446	3,762	3,307	5,443
Per cent sound	87.65	89.16	88.97	95.71	94.74	94.19	91.36	94.22

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	110	113	131	....	....	3,120	....
Sound	3,489	2,539	3,764	....	....	40,032	....
Total	3,599	2,652	3,895	....	....	43,152	....
Per cent sound	96.95	95.71	96.69	....	....	....	92.76

TABLE II.—*Sound and wormy apples from one-spray, demonstration, and unsprayed plats. Siloam Springs, Ark., 1909*—Continued.

PLAT III. ONE SPRAY (VERMOREL NOZZLES).

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	397	298	286	431	321	247	231	200
Sound	4,352	3,187	2,458	2,221	1,920	3,323	2,650	1,792
Total	4,749	3,485	2,744	2,652	2,241	3,570	2,881	1,992
Per cent sound	91.65	91.45	89.58	83.79	85.73	93.09	91.99	89.96

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	234					2,645	
Sound	1,986					23,889	
Total	2,220					26,534	
Per cent sound	89.46						90.03

PLAT IV. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	36	41	93	16	22	23	57	57
Sound	3,500	1,849	4,983	1,649	3,123	1,642	2,439	3,115
Total	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172
Per cent sound	98.99	97.83	98.17	99.04	99.31	98.62	97.72	98.21

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	154	67	41			607	
Sound	4,637	1,890	3,017			31,844	
Total	4,791	1,957	3,058			32,451	
Per cent sound	96.79	96.58	98.66				98.12

PLAT V. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	795	679	217	716	450	823	697	287
Sound	1,765	1,004	778	822	756	1,678	2,124	869
Total	2,560	1,683	995	1,538	1,206	2,501	2,821	1,156
Per cent sound	68.95	59.66	78.20	53.45	62.68	67.10	75.30	75.18

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	652	859	709	592	644	8,120	
Sound	1,671	1,399	1,010	1,016	1,416	16,308	
Total	2,323	2,258	1,719	1,608	2,060	24,428	
Per cent sound	71.94	61.18	58.76	63.19	68.74		66.74

Plat I, which received the one-spray treatment, shows an average of 92.76 per cent of fruit free from the codling moth, the percentages for individual trees ranging from 87.65 to 96.95. The total number

of apples counted from this plat was 43,152. Plat III received the drenching mist spray with Vermorel nozzle and shows for the individual trees a range in percentage of fruit free from the codling moth of 83.79 to 91.99, with an average for all trees of 90.03. There were 26,534 apples examined. Plat IV, which received the demonstration treatment of five applications, shows a total from the 11 trees of 98.12 per cent of fruit free from the codling moth, with a range for individual trees of 96.58 to 99.31 per cent, and the total number of apples counted was 32,451. Plat V (the unsprayed block) shows, for the 13 trees from which counts were made, 66.74 per cent of fruit free from the codling moth, the range being from 53.45 to 78.20 per cent, the total number of apples counted being 24,428. Demonstration plat, No. IV, shows an increase over the unsprayed trees of 31.38 per cent of uninjured fruit and an increase of 5.36 per cent of uninjured fruit over the one-spray block (Plat I).

The percentages of sound fruit from Plats I and III show very little difference in favor of a coarse spray over a mist spray; that is, 2.73 per cent in favor of the former.

In Table III are shown the places of entrance into apples of the total larvæ for the season for each tree of each plat and also the percentages, by plats, entering the fruit at the calyx, side, and stem. These data have been given in order to show what effect the methods of spraying might have upon the places of entrance into fruit by larvæ. The unsprayed plat (Plat V) may be taken to indicate the normal behavior of the larvæ and shows that of the first brood 76.84 per cent and of the second brood 80.34 per cent entered the apples at the calyx ends.

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909.*

PLAT I. ONE SPRAY (BORDEAUX NOZZLES).

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	......	......	......	......	......	......	......	1
Side	5	4	1	3	1	2	1	2
Stem	......	......	......	......	......	......	......	......
Total	5	4	1	3	1	2	1	3
Second brood:								
Calyx	91	70	69	20	32	31	54	55
Side	557	400	323	77	137	172	198	235
Stem	53	48	27	18	12	24	34	25
Total	701	518	419	115	181	227	286	315

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT I. ONE SPRAY—Continued.

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	2	1	......	......	......	4	15.38	......
Side	1	1	1	......	......	22	84.62	......
Stem	......	......	......	......	......	......	......	......
Total	3	2	1	......	......	26	......	......
Second brood:								
Calyx	32	24	26	......	......	504	15.97	......
Side	110	80	89	......	......	2,378	75.30	......
Stem	11	9	15	......	......	276	8.73	......
Total	153	113	130	......	......	3,158	......	3,184

PLAT III. ONE SPRAY (VERMOREL NOZZLES).

Total number of larvæ and places of entrance of fruit for each tree, by broods.								
Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	2	......	......	......	......	......	1	......
Side	4	4	2	1	1	1	9	......
Stem	......	......	......	......	......	......	......	......
Total	6	4	2	1	1	1	10	......
Second brood:								
Calyx	141	103	105	158	96	70	64	66
Side	208	163	157	224	198	154	136	121
Stem	49	28	24	50	30	25	21	16
Total	398	294	286	432	324	249	221	203

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	......	......	......	......	......	3	12.00	......
Side	......	......	......	......	......	22	88.00	......
Stem	......	......	......	......	......	......	......	......
Total	......	......	......	......	......	25	......	......
Second brood:								
Calyx	74	......	......	......	......	877	33.20	......
Side	147	......	......	......	......	1,508	57.10	......
Stem	13	......	......	......	......	256	9.70	......
Total	234	......	......	......	......	2,641	......	2,666

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT IV. DEMONSTRATION.

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	....	....	....	....	....	....	....	2
Side	1	....	4	....	1	....	....	1
Stem	....	....	2	....	....	....	....	1
Total	1	....	6	....	1	....	....	4
Second brood:								
Calyx	14	26	41	6	16	16	32	29
Side	20	14	45	10	5	7	25	21
Stem	1	....	3	....	1	1	1	3
Total	35	40	89	16	22	24	58	53

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	4	1	1	......	......	8	36.40	....
Side	3	....	....	......	......	10	45.40	....
Stem	....	1	....	......	......	4	18.20	....
Total	7	2	1	......	......	22	....	....
Second brood:								
Calyx	79	47	22	......	......	328	55.50	....
Side	65	18	17	......	......	247	41.80	....
Stem	5	....	1	......	......	16	2.70	....
Total	149	65	40	......	......	591	....	613

PLAT V. UNSPRAYED.

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	64	102	32	132	52	96	45	25
Side	23	26	4	33	14	15	12	7
Stem	6	5	1	5	10	6	7	4
Total	93	133	37	170	76	117	64	36
Second brood:								
Calyx	579	464	139	463	295	588	513	197
Side	102	67	34	69	58	125	94	49
Stem	28	23	7	26	18	31	32	6
Total	709	554	180	558	371	744	639	252

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT V. UNSPRAYED—Continued.

Brood and place of entrance.	Number of larvæ for each tree.					Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	31	258	55	63	133	1,088	76.84	....
Side	9	36	19	23	33	254	17.94	....
Stem	2	12	4	1	11	74	5.27	....
Total	42	306	78	87	177	1,416	....	....
Second brood:								
Calyx	489	458	535	398	353	5,471	80.34	....
Side	98	89	81	94	96	1,056	15.51	....
Stem	28	11	29	29	15	283	4.15	....
Total	615	558	645	521	464	6,810	....	8,226

In the case of the sprayed plats, as would be expected, the proportion entering at the calyx is greatly reduced, and there is a corresponding increase in the proportion entering the fruit at the side, owing to the lesser efficiency of the spray at the latter place. This is shown for each of the plats in Table IV.

TABLE IV.—*Places of entering apples, shown in percentages, of total larvæ of first and second broods of the codling moth combined. Siloam Springs, Ark., 1909.*

Plat No.	Percentage of larvæ entering—				Total larvæ, first brood.	Total larvæ, second brood.	Total larvæ, first and second broods.
	Calyx.	Side.	Stem.	Total			
I. One-spray, Bordeaux nozzles	15.96	75.38	8.66	100.00	26	3,158	3,184
III. One-spray, Vermorel nozzles	33.01	57.39	9.60	100.00	25	2,641	2,666
IV. Demonstration	54.81	41.93	3.26	100.00	22	592	613
V. Unsprayed	79.73	15.93	4.34	100.00	1,416	6,810	8,226

As between the several sprayed plats there is considerable variation in the number of apples wormy at calyx, side, and stem, which is of significance in connection with the character of the treatments given. To compare these points better Table V has been prepared.

TABLE V.—*Efficiency of the one-spray and demonstration treatments as shown by the percentages of wormy apples. Siloam Springs, Ark., 1909.*

Plat No.	Percentage of wormy apples.[a]				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
I. One-spray, Bordeaux nozzles	1.18	5.54	0.64	7.24	3,120	43,152
III. One-spray, Vermorel nozzles	3.32	5.57	.97	9.97	2,654	26,534
IV. Demonstration	1.03	.79	.20	1.88	607	32,451
V. Unsprayed	26.85	5.36	1.46	33.26	8,120	24,428

[a] As some apples were entered at more than one place, the sums of the percentages for calyx, side, and stem slightly exceed the total percentages of wormy apples.

A comparison of the figures for the different plats in Table V shows as to calyx entrance for the two broods about the same degree of protection in the case of Plats I and IV, while as between Plats I and III, both involving the one-spray method, there is a difference in favor of a coarser as against a mist spray of 1.14 per cent of the total crop. The figures on side entrance show that neither of the one-spray treatments afforded any protection to the side of the fruit, while the demonstration treatment saved 4.57 per cent of the crop by preventing side entrance. In comparing the total efficiency of the different treatments, it will be seen that there was a saving of 26.02 per cent of the crop in Plat I, 23.29 per cent in Plat III, and 31.38 per cent in Plat IV. The superiority of the demonstration treatment was mostly due to the prevention of side worminess.

In order to determine what effect the respective treatments might have on the proportion of fruit which dropped and that which remained on the trees until picking time the following table (Table VI) was prepared from the data in the previous tables:

TABLE VI.—*Comparison of amounts of drop-fruit during season on the several plats. Siloam Springs, Ark., 1909.*

Plat No.	Number of trees.	Fruit from ground. First brood. Wormy.	Sound.	Total.	Per cent sound.	Second brood. Wormy.	Sound.	Total.	Per cent sound.
I.	11	26	10,202	10,228	99.74	1,449	7,663	9,112	84.09
III.	9	25	5,314	5,339	99.53	1,249	5,997	7,246	82.76
IV.	11	22	8,970	8,992	99.74	240	5,513	5,753	95.82
V.	13	945	8,109	9,054	89.56	5,471	5,742	11,213	51.20

Plat No.	Number of trees.	Fruit from tree. Wormy.	Sound.	Total.	Per cent sound.	Total fruit. Wormy.	Sound.	Total.	Per cent sound.	Percentage of drop-fruit.
I.	11	1,645	22,167	23,812	93.09	3,120	40,032	43,152	92.76	44.81
III.	9	1,371	12,578	13,949	90.17	2,645	23,889	26,534	90.03	47.42
IV.	11	345	17,361	17,706	98.05	607	31,844	32,451	98.12	45.43
V.	13	1,704	2,457	4,161	59.04	8,120	16,308	24,428	66.76	82.96

As will be noted, the highest percentage of drop-fruit was on the unsprayed plat, namely, 82.96, with 47.42 per cent drop-fruit from Plat III. Plats I and IV (the one-spray and demonstration treatments) show a difference in favor of the demonstration plat of only 0.62 per cent, an amount practically negligible. The percentage of drop-fruit, including fallen fruit from all causes, is shown, but it should be remembered that fruit from all plats, except the check, was largely protected from fungous troubles by applications of Bordeaux mixture.

THE PLUM CURCULIO.

Throughout the season the drop-fruit and the fruit on trees at picking time from four of the plats in the Jones orchard were carefully examined as to injury by the plum curculio. The results of examinations are given in detail in Table VII.

TABLE VII.—*Injury by plum curculio for entire season on Plats I, III, IV, and V, sprayed in the codling-moth experiments. Siloam Springs, Ark., 1909.*

PLAT I. ONE-SPRAY.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of punctures	1,979	1,713	2,613	683	268	1,012	638	1,200
Number of fruit punctured	1,179	915	687	387	208	532	370	706
Number of sound fruit	4,510	3,898	3,109	2,363	3,238	3,236	2,937	4,737
Number of fruit	5,689	4,813	3,796	2,750	3,446	3,768	3,307	5,443
Per cent free from injury	79.27	80.98	81.90	85.92	93.96	85.88	88.81	87.02

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	642	319	642			11,709	
Number of fruit punctured	364	216	335			5,899	
Number of sound fruit	3,280	2,436	3,560			37,304	
Number of fruit	3,644	2,652	3,895			43,203	
Per cent free from injury	90.01	91.85	91.39				86.34

PLAT III. ONE-SPRAY.

	Number of punctured and sound fruit etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of punctures	2,321	721	919	788	560	1,790	1,756	732
Number of fruit punctured	1,051	349	533	368	358	795	727	372
Number of fruit free from injury	3,698	2,339	2,211	2,284	1,883	2,775	2,154	1,620
Number of fruit	4,749	2,688	2,744	2,652	2,241	3,570	2,881	1,992
Per cent free from injury	77.86	87.01	80.57	86.12	84.02	77.73	74.76	81.32

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	1,629					11,216	
Number of fruit punctured	727					5,280	
Number of fruit free from injury	1,493					20,457	
Number of fruit	2,220					25,737	
Per cent free from injury	67.25						79.48

TABLE VII.—*Injury by plum curculio for entire season on Plats I, III, IV, and V, sprayed in the codling-moth experiments. Siloam Springs, Ark., 1909*—Continued.

PLAT IV. DEMONSTRATION.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of punctures	1,293	562	773	98	430	432	1,025	877
Number of fruit punctured	746	301	437	74	266	200	498	467
Number of fruit free from injury	2,790	1,589	4,639	1,591	2,879	1,465	1,998	2,705
Number of fruit	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172
Per cent free from injury	78.90	84.07	91.39	95.55	91.54	87.98	80.04	85.27

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	13,129	254	1,429	....	....	10,302	....
Number of fruit punctured	3,656	140	769	....	....	5,554	....
Number of fruit free from injury	135	1,817	2,289	....	....	26,897	....
Number of fruit	4,791	1,957	3,058	....	....	32,451	....
Per cent free from injury	65.43	92.84	74.85	....	....	....	82.88

PLAT V. UNSPRAYED.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of puncture	6,623	6,230	4,331	10,068	3,372	9,527	14,727	4,714
Number of fruit punctured	2,130	1,595	948	1,522	999	2,299	2,724	1,070
Number of fruit free from injury	430	106	47	16	207	202	97	86
Number of fruit	2,560	1,701	995	1,538	1,206	2,501	2,821	1,156
Per cent free from injury	16.79	6.23	4.72	1.04	17.16	8.07	3.43	7.43

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	6,143	8,707	6,921	5,984	6,739	94,086	....
Number of fruit punctured	1,936	2,117	1,605	1,517	1,750	22,212	....
Number of fruit free from injury	387	141	114	91	310	2,234	....
Number of fruit	2,323	2,258	1,719	1,608	2,060	24,446	....
Per cent free from injury	16.65	6.24	6.63	5.65	15.04	....	8.85

All punctures, whether egg or feeding, are classed together under "Number of punctures." The total percentage of fruit free from curculio injury includes fruit entirely free from feeding and egg punctures, and has no reference to injury from other insects, as the codling moth or lesser apple worm. Curiously, in the Siloam Springs work the one-spray block (Plat I) shows the maximum percentage of fruit free from curculio attack, injury on the demonstration plat exceeding in this regard that on the one-spray plat by 3.46 per cent. It should be noted, however, that Plat IV was adjacent to the unsprayed block (see fig. 2) and there was unquestionably considerable overflow of curculio, as on this latter the beetles were quite abundant, as shown by the low total percentage of uninjured fruit, namely, 8.85 per cent. In view of the habits of the curculio in ovipositing and feeding over a considerable period (six to eight weeks or more), the results from the one-spray method are the more surprising, and it would appear that the single treatment resulted in their almost complete destruction.

In Table VIII are brought together data showing the effects of the treatments in the control of the three principal insect enemies of the fruit, namely, the codling moth, the plum curculio, and the lesser apple worm (*Enarmonia prunivora* Walsh). The value of the one-spray method is here put to the severest possible test so far as controlling insect enemies of the fruit is concerned. It will be noted that when these three insects are taken into account somewhat better results were secured from Plat IV, which received the demonstration treatment, namely, 81.19 per cent sound fruit, as against 79.60 per cent sound fruit from the one-spray plat. The unsprayed plat (V) shows a very low percentage of fruit free from injury by these three insects, namely 6.94 per cent.

TABLE VIII.—*Effect of treatments on the three principal fruit insects and total percentage of sound fruit. Siloam Springs, Ark., 1909.*

PLAT I. ONE-SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	1,179	915	687	387	208	532	370	706
Injured by codling moth	703	522	419	118	181	222	286	315
Injured by lesser apple worm	71	74	41	6	31	17	19	30
Number injured apples	1,778	1,403	1,062	486	409	739	652	991
Number uninjured apples	3,911	3,410	2,734	2,264	3,037	3,023	2,655	4,452
Total number apples	5,689	4,813	3,796	2,750	3,446	3,762	3,307	5,443

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	364	216	335			5,899	86.34	
Injured by codling moth	110	113	131			3,120	92.74	
Injured by lesser apple worm	10	5	5			309	99.29	
Number injured apples	473	349	460			8,802		
Number uninjured apples	3,126	2,303	3,433			34,348		79.60
Total number apples	3,599	2,652	3,895			43,152		

PLAT III. ONE-SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	1,051	349	533	368	358	795	727	372
Injured by codling moth	397	298	286	431	321	247	231	200
Injured by lesser apple worm	29	19	14	32	40	22	26	12
Number injured apples	1,363	525	772	806	684	1,010	919	551
Number uninjured apples	3,386	2,960	1,972	1,846	1,557	2,560	1,962	1,441
Total number apples	4,749	3,485	2,744	2,652	2,241	3,570	2,881	1,992

TABLE VIII.—*Effect of treatments on the three principal fruit insects and total percentage of sound fruit. Siloam Springs, Ark., 1909*—Continued.

PLAT III. ONE-SPRAY—Continued.

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	727					5,280	79.48	
Injured by codling moth	234					2,645	90.03	
Injured by lesser apple worm	9					203	99.24	
Number injured apples	786					7,416		
Number uninjured apples	1,434					19,118		72.05
Total number apples	2,220					26,534		

PLAT IV. DEMONSTRATION.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	746	301	437	74	266	200	498	467
Injured by codling moth	36	41	93	16	22	23	57	57
Injured by lesser apple worm	6	1	6	1	0	2	3	0
Number injured apples	826	332	509	90	287	222	545	518
Number uninjured apples	2,710	1,558	4,567	1,575	2,858	1,443	1,951	2,654
Total number apples	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	1,656	140	769			5,554	82.88	
Injured by codling moth	154	67	41			607	98.12	
Injured by lesser apple worm	14	6	3			42	99.87	
Number injured apples	1,761	207	806			6,103		
Number uninjured apples	3,030	1,750	2,252			26,348		81.19
Total number apples	4,791	1,957	3,058			32,451		

PLAT V. UNSPRAYED.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	2,130	1,595	948	1,522	999	2,299	2,724	1,070
Injured by codling moth	795	679	217	716	450	823	697	287
Injured by lesser apple worm	213	140	52	222	89	224	309	91
Number injured apples	2,250	1,605	959	1,528	1,072	2,355	2,740	1,076
Number uninjured apples	310	78	36	10	134	146	81	80
Total number apples	2,560	1,683	995	1,538	1,206	2,501	2,821	1,156

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	1,936	2,117	1,605	1,517	1,750	22,212	8.85	
Injured by codling moth	652	859	709	592	644	8,120	66.75	
Injured by lesser apple worm	120	218	139	174	77	2,068	91.50	
Number injured apples	1,987	2,148	1,631	1,556	1,824	22,731		
Number uninjured apples	336	110	88	52	236	1,697		6.94
Total number apples	2,323	2,258	1,719	1,608	2,060	24,428		

EXPERIMENTS IN VIRGINIA.

The experiments in Virginia were carried out in two localities, namely, at Crozet, in the orchard of W. S. Ballard, and at Mount Jackson, in the orchard of the Strathmore Orchard Company.

W. S. BALLARD'S ORCHARD.

W. S. Ballard's orchard is located in the eastern foothills of the Blue Ridge Mountains and is composed mostly of the Yellow Newtown (Albemarle Pippin) variety, which sort was used exclusively

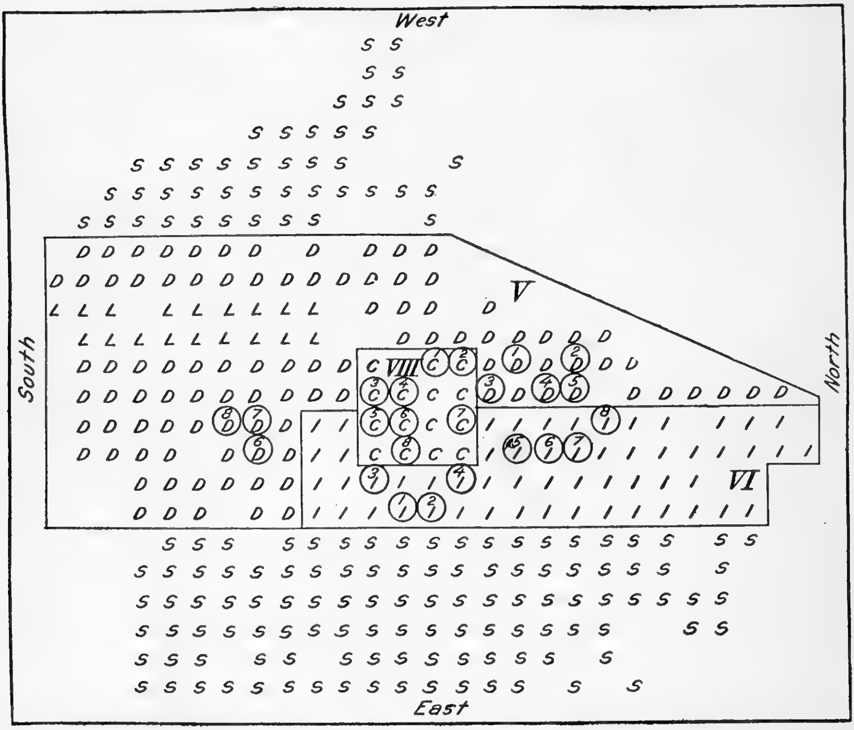

FIG. 35.—Diagram showing arrangement of plats and trees in the W. S. Ballard orchard near Crozet, Va. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Variety, Yellow Newtown (Albemarle Pippin). Trees marked *S* sprayed by owner.

in the experiments. The location of the trees sprayed, with reference to adjacent trees in the orchard, is shown in figure 35. The surrounding trees not included in the experiment were sprayed by the owner. The size of the trees and general character of the location are shown in Plate X, figure 2.

THE CODLING MOTH.

The treatments given and dates of applications are shown in Table IX.

TABLE IX.—*Dates of applications for codling moth and plum curculio, one-spray method. Crozet, Va., 1909.*

Date of application.	Plat V. (Demonstration.)	Plat VI. (One-spray method.)	Plat VIII. (Unsprayed.)
First application, April 27 (after falling of petals).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead 2 pounds to 50 gallons Bordeaux mixture (2-2-50). Pressure 120 to 140 pounds.	Drenched with arsenate of lead 2 pounds to 50 gallons Bordeaux mixture (2-2-50). Pressure 125-160 pounds. Seneca nozzles. 11 gallons per tree.	Unsprayed.
Second application, May 24.	.....do	Bordeaux mixture only (2-2-50). Not drenched.	Do.
Third application, June 26.	.....do	.....do	Do.
Fourth application, July 26-27.	.....do	.....do	Do.

Plat V (demonstration) received four applications in all, the Vermorel nozzle being used. The effort was made to spray thoroughly, but none of the trees was drenched. Plat VI (one-spray method) was thoroughly drenched, using Seneca nozzles, applying an average of 11 gallons per tree. This plat received three subsequent applications of Bordeaux mixture only, as shown in the schedule, to protect the fruit from possible infection by bitter rot. Plat VIII was left unsprayed throughout the season for purposes of comparison.

The first application, on April 27, was given just after most of the petals had fallen, and conditions were favorable for the work except that showers interrupted the spraying for about one hour. At the time of the second application, May 24, the weather was showery, but spraying was finished without serious interruption. The third application, on June 26, was interrupted near the close of the work by rain, while the fourth application, on July 26, was made under very favorable conditions, the weather being clear and dry. Comparatively little bitter rot developed during the season, even on the unsprayed plat. A heavy hail, however, which occurred during late June, badly injured the fruit and foliage. It was noticed that the hail injury to the fruit resulted in a much greater proportion of codling-moth larvæ entering on the side, and this fact must be taken into account in the consideration of the results.

Table X gives the total wormy fruit and fruit free from codling-moth injury for the entire season for the eight count trees of each plat, the numbers of the trees in the figure agreeing with those in the table.

TABLE X.—*Number of sound and wormy apples for each tree from one-spray, demonstration, and unsprayed plats. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	90	115	68	191	173	49	54	87	827	....
Sound	712	1,344	651	2,224	1,859	1,259	2,958	2,243	13,250	....
Total	802	1,459	719	2,415	2,032	1,308	3,012	2,330	14,077	....
Per cent sound	88.78	92.12	90.55	92.10	91.49	96.26	98.21	96.27	....	94.13

PLAT VI. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	498	367	627	1,681	445	362	391	462	3,320	....
Sound	2,080	2,166	4,478	1,150	2,800	1,617	1,650	1,577	17,518	....
Total	2,578	2,533	5,105	1,318	3,245	1,979	2,041	2,039	20,838	....
Per cent sound	80.30	85.52	87.72	87.26	86.29	81.71	80.90	77.35	....	84.07

PLAT VIII. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	1,165	1,593	545	560	1,641	1,444	1,089	1,001	9,038	....
Sound	2,258	2,089	271	456	1,470	1,544	904	1,206	10,198	....
Total	3,423	3,682	816	1,016	3,111	2,988	1,993	2,207	19,236	....
Per cent sound	65.97	56.79	33.22	44.89	47.90	51.68	45.31	54.65	....	53.02

Plat V, which received the demonstration treatment, gave 94.13 per cent fruit free from codling-moth injury, as against 84.07 per cent fruit free from this insect on the one-spray plat, a difference in favor of the demonstration treatment of 10.06 per cent. The check or unsprayed plat (VIII) shows 53.02 per cent fruit free from codling-moth injury, and there is thus a gain in sound fruit by the demonstration treatment of 41.11 per cent and by the one-spray method a gain of 31.05 per cent of sound fruit. As will be seen from the foregoing table, there were counted in Plats V, VI, and VIII, respectively, 14,077, 20,838, and 19,236 apples, a total for all plats of 54,151. Undoubtedly the results from the one-spray plat are less favorable than would have been the case had there been no hail. The injured places on the sides of the fruit permitted ready entrance of the larvæ, as indicated on all plats by the relatively high percentage of larvæ which entered the fruit on the side. This condition is shown in Table XI, which gives the places of entrance of the fruit for each tree of each plat for the total larvæ of the two broods throughout the season.

TABLE XI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Crozet, Va., 1909.*

Place of entrance.	Total number of larvæ of fruit for each tree, first and second broods combined.								Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.			
PLAT V. DEMONSTRATION.											
First and second broods:											
Calyx	8	6	5	13	15	2	4	11	64	7.73	....
Side	76	105	59	159	148	46	46	68	707	85.49	....
Stem	6	4	4	19	10	1	4	8	56	6.78	....
Total	90	115	68	191	173	49	54	87	827	100.00	827
PLAT VI. ONE SPRAY.											
First and second broods:											
Calyx	35	12	26	7	12	23	17	19	151	4.55	....
Side	443	331	567	150	407	319	344	415	2,976	89.64	....
Stem	20	24	34	11	26	20	30	28	193	5.81	....
Total	498	367	627	168	445	362	391	462	3,220	100.00	3,220
PLAT VIII. UNSPRAYED.											
First and second broods:											
Calyx	527	888	320	258	878	677	512	493	4,553	50.38	....
Side	483	508	158	231	561	620	439	429	3,429	37.94	....
Stem	155	197	67	71	202	147	138	79	1,056	11.68	....
Total	1,165	1,593	545	560	1,641	1,444	1,089	1,001	9,038	100.00	9,038

The efficiency of the one-spray and demonstration treatments in preventing worminess is shown in condensed form in Table XII. Here it will be seen that the one-spray method was nearly as effective as the demonstration in preventing calyx entrance, but gave little benefit in regard to side infestation.

TABLE XII.—*Efficiency of the different treatments as shown by the percentages of wormy apples. Crozet, Va., 1909.*

Plat No.	Percentage of wormy apples.				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		
V. Demonstration	0.45	5.02	0.40	5.87	827	14,077
VI. One-spray	0.73	14.28	0.92	15.93	3,320	20,838
VIII. Unsprayed	23.67	17.82	5.49	46.98	9,038	19,236

THE PLUM CURCULIO.

The effect of the treatments in the W. S. Ballard orchard in controlling the plum curculio on Plats V, VI, and VIII is shown in Table XIII. Egg and feeding punctures are combined in the table under "No. punctures."

TABLE XIII.—*Injury by plum curculio for entire season, Plats V, VI, and VIII. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

	Number of punctured and sound apples, etc., per tree in each plat.								Total for plats.	Total per cent of fruit free from injury.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.		
No. punctures	157	275	163	524	668	162	395	328	2,672	....
No. fruit punctured	115	187	103	345	463	114	267	252	1,846	....
No. sound fruit	687	1,272	616	2,070	1,569	1,194	2,747	2,076	12,231	....
No. fruit	802	1,459	719	2,415	2,032	1,308	3,014	2,328	14,077	....
Per cent free from injury	85.66	87.18	85.67	85.71	77.21	91.28	91.14	89.17	....	86.89

PLAT VI. ONE SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of fruit free from injury.
No. punctures	1,510	1,290	2,143	360	1,095	647	775	823	8,644	....
No. fruit punctured	961	730	1,347	238	719	405	521	511	5,432	....
No. sound fruit	1,617	1,803	3,758	1,080	2,526	1,574	1,520	1,528	15,406	....
No. fruit	2,578	2,533	5,105	1,318	3,245	1,979	2,041	2,039	20,838	....
Per cent free from injury	62.72	71.17	73.61	81.94	77.84	79.53	74.96	74.93	....	73.93

PLAT VIII. UNSPRAYED.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of fruit free from injury.
No. punctures	2,746	2,571	705	962	2,490	1,939	1,865	2,300	15,578	....
No. fruit punctured	1,255	1,571	437	531	1,415	1,193	1,098	1,285	8,785	....
No. sound fruit	2,168	2,111	379	485	1,696	1,795	882	806	10,322	....
No. fruit	3,423	3,682	816	1,016	3,111	2,988	1,980	2,091	19,107	....
Per cent free from injury	63.30	57.33	57.33	46.44	47.73	60.00	44.54	38.54	....	54.02

The percentage of fruit uninjured by the curculio in the demonstration block, 86.89 per cent, shows a gain over that of the one-spray plat, 73.93 per cent, of 12.96 per cent, and the gain in percentage of uninjured fruit on the demonstration over the unsprayed plat is 32.87.

ORCHARD OF STRATHMORE ORCHARD COMPANY.

The orchard of the Strathmore Orchard Company is located near Mount Jackson, in the Shenandoah Valley of Virginia. The size of the trees and general appearance of the orchard are indicated in Plate XI, figure 1. The location of the trees under experiment with respect to the rest of the orchard is shown in figure 36. All trees not in the experiment were sprayed by the owners. The treatments given and dates of application are stated in Table XIV.

TABLE XIV.—*Dates of applications for codling moth and plum curculio, one-spray method. Mount Jackson, Va., 1909.*

Date of application.	Plat XIII. (Demonstration.)	Plat XV. (One-spray method.)	Plat XVII. (Unsprayed.)
First application, May 6–7 (after falling of petals).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (1–1–50). Pressure 120 to 140 pounds. 4.7 gallons per tree.	Drenched with arsenate of lead, 2 pounds to 50 gallons water. Pressure 175 pounds. Seneca nozzles. 8.1 gallons per tree.	Unsprayed.
Second application, May 28–29.	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (2–2–50).	Bordeaux mixture only (2–2–50). Not drenched.	Do.
Third application, July 8–9.	.....do	.....do	Do.

FIG. 1.—VIEW IN ORCHARD OF THE STRATHMORE ORCHARD COMPANY, NEAR MOUNT JACKSON, VA. (ORIGINAL.)

FIG. 2.—VIEW IN THE E. H. HOUSE ORCHARD, NEAR SAUGATUCK, MICH. (ORIGINAL.)

The demonstration plat (XIII) received in all three treatments of a combined Bordeaux mixture and arsenate of lead spray. Plat XV (one-spray method) received only one arsenate of lead treatment just after the falling of the petals, but two additional applications of Bordeaux mixture were given to protect the fruit and foliage from fungous diseases. Plat XVII was left unsprayed throughout. The Ben Davis variety of apple was used entirely in the experiments.

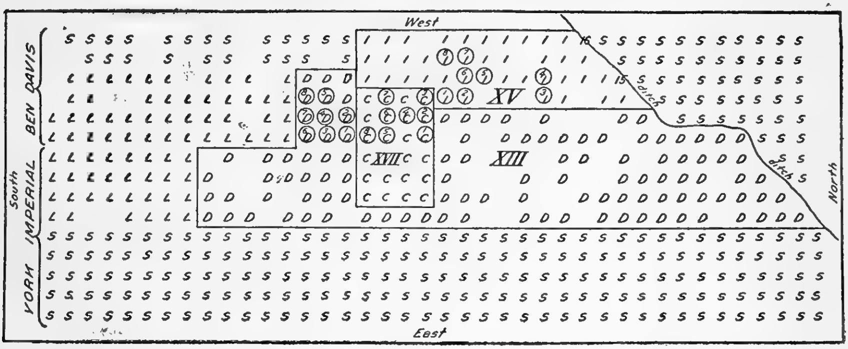

FIG. 36.—Diagram showing arrangement of plats and trees in the orchard of the Strathmore Orchard Co., near Mount Jackson, Va. Trees marked *S* sprayed by the owner; trees marked *L* used for experiments with lime-sulphur wash. Circles indicate count trees, the numbers agreeing with those in the tables.

THE CODLING MOTH.

The results of the respective treatments in the control of the codling moth are shown in Table XV.

TABLE XV.—*Number of sound and wormy apples for each tree from one-spray, demonstration, and unsprayed plats. Mount Jackson, Va., 1909.*

PLAT XIII. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
Wormy	200	136	155	83	173	168	119	150	1,184	
Sound	1,666	1,172	3,311	625	1,494	3,618	944	2,278	15,108	
Total	1,866	1,308	3,466	708	1,667	3,786	1,063	2,428	16,292	
Per cent sound	89.29	89.61	95.53	88.28	89.69	95.57	88.81	93.83		92.74

PLAT XV. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
Wormy	250	253	86	186	250	219	122	257	1,623	
Sound	3,577	3,404	589	730	1,429	3,261	847	4,042	17,879	
Total	3,827	3,657	675	916	1,679	3,480	969	4,299	19,502	
Per cent sound	93.49	93.09	87.26	79.70	85.12	93.71	87.41	94.03		91.68

PLAT XVII. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
Wormy	1,913	1,425	865	983	1,538	1,792	2,027	1,247	11,790	
Sound	2,013	1,684	965	524	1,651	2,361	3,094	1,548	13,840	
Total	3,926	3,109	1,830	1,507	3,189	4,153	5,121	2,795	25,630	
Per cent sound	51.23	54.17	52.19	34.78	51.78	56.86	60.42	55.42		54.00

The influence of the treatments on the places of entrance of fruit by the larvæ of the first and second broods combined for the respective plats is shown in Table XVI.

TABLE XVI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Mount Jackson, Va., 1909.*

PLAT XIII. DEMONSTRATION.

Place of entrance.	Total number of larvæ of fruit for each tree, first and second broods combined.								Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.			
First and second broods:											
Calyx	32	14	15	16	20	26	15	24	162	13.68	....
Side	154	111	122	58	136	125	92	116	914	77.20	....
Stem	14	11	18	9	17	17	12	10	108	9.12	....
Total	200	136	155	83	173	168	119	150	1,184	100.00	1,184

PLAT XV. ONE SPRAY.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	13	32	6	16	25	19	18	17	146	8.99	....
Side	190	193	74	143	173	183	91	214	1,261	77.70	....
Stem	47	28	6	27	52	17	13	26	216	13.31	....
Total	250	253	86	186	250	219	122	257	1,623	100.00	1,623

PLAT XVII. UNSPRAYED.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	1,466	1,063	699	762	1,232	1,377	1,584	969	9,152	77.62	....
Side	332	265	119	141	203	295	353	209	1,917	16.26	....
Stem	115	97	47	80	103	120	90	69	721	6.12	....
Total	1,913	1,425	865	983	1,538	1,792	2,027	1,247	11,790	100.00	11,790

For more ready comparison of the efficiency of the treatments, Table XVII is given, from which it will be seen that the demonstration and the one-spray treatments were about equally effective in protecting the calyx and that neither was satisfactory in controlling worms entering the side. The difference in total efficiency between the demonstration and the one-spray plats is quite small, namely, 1.06 per cent in favor of the former. The unsprayed trees show 46 per cent of wormy fruit, so there is a total saving of 38.44 per cent of the crop by the demonstration treatment and 37.68 per cent by the one-spray.

TABLE XVII.—*Efficiency of the one-spray and demonstration treatments as shown by the percentages of wormy apples. Mount Jackson, Va., 1909.*

Plat No.	Percentage of wormy apples.				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*		
XIII (demonstration)	0.99	5.61	0.66	7.26	1,184	16,292
XV (one-spray)	.75	6.46	1.11	8.32	1,623	19,502
XVII (unsprayed)	35.71	7.48	2.81	46.00	11,790	25,630

THE PLUM CURCULIO.

The plum curculio proved to be unusually destructive in the Strathmore orchard, which had not been plowed for at least two years and had grown up in grass and sod. The results of the respective treatments in the control of this insect are shown in Table XVIII, and as will be noted the percentage of fruit free from curculio injury is in all cases comparatively low. Nevertheless the one-spray treatment shows a gain of 17.08 per cent of fruit free from injury over the demonstration treatment, and a gain of 30.67 per cent of fruit free from injury over the unsprayed trees. The location of the trees in the respective plats does not indicate a more favorable place as regards liability to curculio injury for the one-spray block and the notably higher benefit of the single treatment in the control of the curculio on this plat is not understood.

TABLE XVIII.—*Injury by the plum curculio for entire season, Plats XIII, XV, and XVII. Mount Jackson, Va., 1909.*

PLAT XIII. DEMONSTRATION.

	Number of punctured and sound apples, etc., per tree in each plat.								Total for plat.	Total per cent fruit free from injury.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.		
No. punctures	2,961	2,391	3,067	932	3,013	4,040	1,486	2,869	20,759	....
No. fruit punctured	1,367	755	1,631	441	1,257	2,197	612	1,382	9,642	....
No. sound fruit	499	553	1,835	267	410	1,589	451	1,047	6,651	....
No. fruit	1,866	1,308	3,466	708	1,667	3,786	1,063	2,429	16,293	....
Per cent free from injury	26.79	42.27	52.94	33.71	24.58	41.97	42.42	43.10	....	40.82

PLAT XV. ONE SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plat.	Total per cent fruit free from injury.
No. punctures	2,782	1,800	633	1,032	1,449	2,159	987	3,153	13,995	....
No. fruit punctured	1,507	1,788	303	494	754	1,212	447	1,735	8,240	....
No. sound fruit	2,320	1,869	372	495	925	2,268	522	2,564	11,335	....
No. fruit	3,827	3,657	675	989	1,679	3,480	969	4,299	19,575	....
Per cent free from injury	60.62	51.10	55.11	50.15	55.09	65.17	53.86	59.64	....	57.90

PLAT XVII. UNSPRAYED.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plat.	Total per cent fruit free from injury.
No. punctures	7,336	4,497	2,212	2,888	5,030	6,122	8,779	4,904	41,768	....
No. fruit punctured	3,186	2,226	1,079	1,226	2,399	2,823	3,611	2,107	18,657	....
No. sound fruit	740	883	761	282	790	1,330	1,510	688	6,984	....
No. fruit	3,926	3,109	1,840	1,508	3,189	4,153	5,121	2,795	25,641	....
Per cent free from injury	18.84	28.40	41.35	18.61	24.77	32.04	29.46	24.61	....	27.23

EXPERIMENTS IN MICHIGAN.

The experiments in Michigan were carried out in the vicinity of Saugatuck, in the orchard of Mr. E. H. House. The location of the plats in the orchard and of the count trees in the respective plats is shown in figure 37. The size of the trees is illustrated in Plate XI, figure 2. This orchard included trees of the Wagener, Ben Davis, and Baldwin varieties, and an equal number of trees of each variety was used for counts in the respective plats. As in the work elsewhere, all drop-fruit during the season, as well as that from the trees at picking time, was taken into account and classified as to injury or otherwise. Also the work of the two broods of the codling moth was carefully separated by removing from the trees at the period of maximum maturation of the first-brood larvæ all fruit injured by the first brood, thus eliminating entirely from later counts first-brood work. The infested apples, however, were placed on the ground under the respective trees, so that development of second-brood larvæ would be in no wise interfered with.

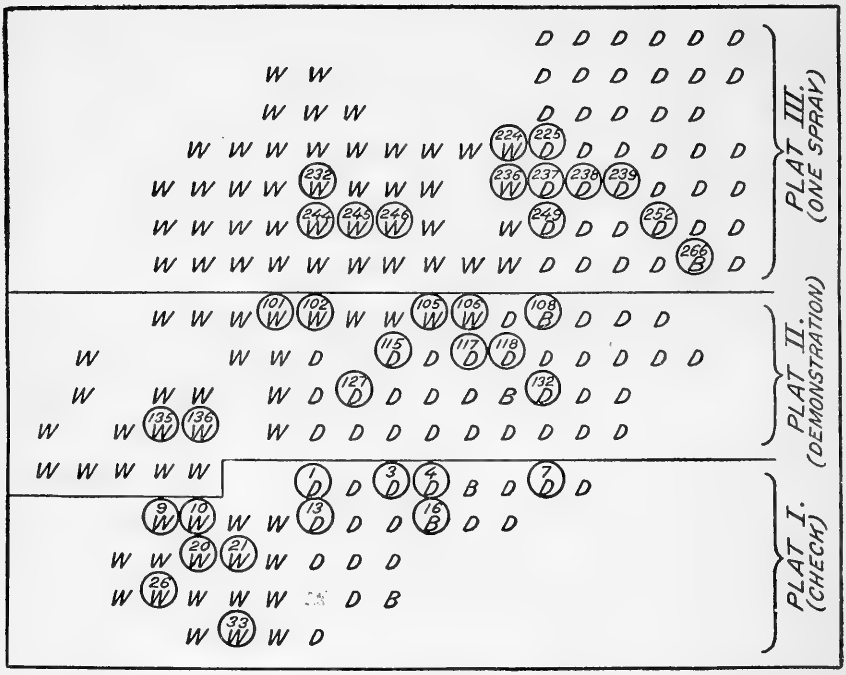

FIG. 37.—Diagram illustrating arrangement of plats and position of trees in the E. H. House orchard, near Saugatuck, Mich.: *D*, Ben Davis; *B*, Baldwin; *W*, Wagener. Count trees are indicated by circles, the numbers agreeing with those in the tables.

The treatments given and dates of application are indicated in Table XIX.

TABLE XIX.—*Dates of applications for the codling moth and plum curculio, one-spray method. Saugatuck, Mich., 1909.*

Date of application.	Plat I. (Unsprayed.)	Plat II. (Demonstration.)	Plat III. (One-spray method.)
First application (before blossoms opened), May 20–21.	Unsprayed....	Not drenched. Vermorel nozzles. Mist spray. Bordeaux mixture (4-4-50).	Drenched. Bordeaux nozzles. Coarse spray. Bordeaux mixture (4-4-50).
Second application, June 3–9, after falling of petals.	.....do........	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (4-4-50). Pressure, 125 pounds.	Drenched. Bordeaux nozzles. Coarse spray. Arsenate of lead, 1 pound to 50 gallons water. Pressure, 175 to 200 pounds.
Third application, June 21–22.	.....do........	.....do....................	Bordeaux mixture only (4-4-50). June 10–11 and again June 21–22.
Fourth application, August 7–9.	.....do........	.....do....................	Bordeaux mixture only (4-4-50).

Plat I was left unsprayed for purposes of comparison. Plat II (demonstration block) received four applications in all, the first before blooming but after cluster buds had opened, to protect the fruit from apple scab, which during some seasons in the lake region is very troublesome. Plat III (one-spray block) received the first scab treatment of Bordeaux mixture only and an additional treatment with arsenate of lead only at the rate of 1 pound to 50 gallons water immediately after the falling of the petals. This treatment was immediately followed by an application of Bordeaux mixture to prevent scab infection, as it was considered unsafe to apply the fungicide so excessively as the one-spray method required in the use of the arsenical. Plat III received two subsequent applications of Bordeaux mixture only, as shown in the schedule of applications, to further insure freedom from apple scab.

THE CODLING MOTH.

The percentages of wormy and sound fruit for the respective plats for the season are shown in Table XX, and the numbers of trees in the table agree with those in the diagram of the orchard (fig. 37).

TABLE XX.—*Sound and wormy fruit from unsprayed, demonstration, and one-spray plats. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.
Wormy	663	752	605	166	946	1,207	416
Sound	3,996	5,033	2,947	1,340	1,805	2,676	2,213
Total	4,659	5,785	3,552	1,506	2,751	3,883	2,629
Per cent sound	85.76	87.00	82.96	88.97	65.61	68.91	84.17

Condition of fruit.	Tree 16.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	Total per cent sound.
Wormy	889	651	404	1,041	669	8,409	....
Sound	1,926	2,632	1,276	2,321	1,301	29,466	....
Total	2,815	3,283	1,680	3,362	1,970	37,875	....
Per cent sound	68.14	80.17	75.95	69.03	66.03	....	77.79

PLAT II. DEMONSTRATION.

Condition of fruit.	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.
Wormy	120	122	48	75	96	72	15
Sound	1,505	1,643	2,112	1,775	5,623	3,950	5,781
Total	1,625	1,765	2,160	1,850	5,719	4,022	5,796
Per cent sound	92.61	93.08	97.77	95.94	98.32	98.20	99.74

TABLE XX.—*Sound and wormy fruit from unsprayed, demonstration, and one-spray plats. Saugatuck, Mich., 1909*—Continued.

PLATE II. DEMONSTRATION—Continued.

Condition of fruit.	Tree 118.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	Total per cent sound.
Wormy	25	91	13	245	76	998	....
Sound	5,188	4,336	4,285	3,978	1,644	41,820	....
Total	5,213	4,427	4,298	4,223	1,720	42,818	....
Per cent sound	99.52	97.94	99.69	94.19	95.58	....	97.66

PLAT III. ONE SPRAY.

Condition of fruit.	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.
Wormy	500	103	396	343	118	41	62
Sound	3,113	4,602	3,061	2,753	2,779	3,510	3,062
Total	3,613	4,705	3,457	3,096	2,897	3,551	3,124
Per cent sound	86.16	97.95	88.54	88.92	95.92	98.84	98.01

Condition of fruit.	Tree 244.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	Total per cent sound.
Wormy	452	340	165	62	46	110	2,738	....
Sound	4,107	4,001	2,743	3,381	1,092	1,925	40,129	....
Total	4,559	4,341	2,908	3,443	1,138	2,035	42,867	....
Per cent sound	90.08	92.16	94.32	98.19	95.95	94.59	....	93.61

In the foregoing table the demonstration plat shows an increase of sound fruit over the one-spray method of 4.05 per cent and over the unsprayed plat of 19.87 per cent. There was less injury on the unsprayed trees than usual for that section, due to the small size of the second brood. Only 13 per cent of the first-brood larvæ from bands transformed to moths.

The effect of the treatments on the places of entrance of fruit by larvæ of the first and second broods is shown in Table XXI.

TABLE XXI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Brood and place of entrance.	Number of larvæ for each tree.							
	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.	Tree 16.
First brood:								
Calyx	133	206	172	65	316	257	168	214
Side	39	24	25	10	28	28	17	40
Stem	5	8	0	0	7	6	4	5
Total	177	238	197	75	351	291	189	259
Second brood:								
Calyx	277	272	274	51	279	316	140	357
Side	213	249	155	39	319	360	87	306
Stem	16	9	15	2	19	30	7	11
Total	506	530	444	92	617	706	234	674

TABLE XXI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909*—Continued.

PLATE I. UNSPRAYED—Continued.

Brood and place of entrance.	Number of larvæ for each tree.					Percentage of larvæ entering.	Total larvæ of first and second broods.
	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.		
First brood:							
Calyx	176	129	442	266	2,544	85.20	....
Side	17	21	68	59	376	12.59	....
Stem	4	5	13	9	66	2.21	....
Total	197	155	523	334	2,986	....	....
Second brood:							
Calyx	208	105	290	183	2,752	50.45	....
Side	240	151	231	181	2,531	46.40	....
Stem	18	6	21	18	172	3.15	....
Total	466	262	542	382	5,455	....	8,441

PLAT II. DEMONSTRATION.

Brood and place of entrance.	Number of larvæ for each tree.							
	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.	Tree 118.
First brood:								
Calyx	....	....	1	....	5	10	2	2
Side	9	12	14	12	8	5	5	4
Stem	....	1	....	....	1	....	....	....
Total	9	13	15	12	14	15	7	6
Second brood:								
Calyx	....	....	....	....	2	....	....	1
Side	146	155	41	81	95	73	8	19
Stem	....	....	....	....	....	....	....	....
Total	146	155	41	81	97	73	8	20

Brood and place of entrance.	Number of larvæ for each tree.					Percentage of larvæ entering.	Total larvæ of first and second broods.
	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.		
First brood:							
Calyx	8	1	....	2	31	20.95	....
Side	7	1	27	11	115	77.70	....
Stem	....	....	....	....	2	1.35	....
Total	15	2	27	13	148	....	....
Second brood:							
Calyx	1	....	1	1	6	.52	....
Side	95	11	320	93	1,137	99.30	....
Stem	1	....	1	....	2	.18	....
Total	97	11	322	94	1,145	....	1,293

TABLE XXI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909*—Continued.

PLAT III. ONE SPRAY.

Brood and place of entrance.	Number of larvæ for each tree.							
	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.	Tree 244.
First brood:								
Calyx	5	3	....	2	....	2	1	3
Side	86	6	15	24	7	5	2	31
Stem	2	1	....	1	....	....	....	....
Total	93	10	15	27	7	7	3	34
Second brood:								
Calyx	4	1	6	4	1	1	1	4
Side	356	141	416	370	161	43	75	492
Stem	9	....	....	4	....	....	....	2
Total	369	142	422	378	162	44	76	498

Brood and place of entrance.	Number of larvæ for each tree.						Percentage of larvæ entering.	Total larvæ of first and second broods.
	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.		
First brood:								
Calyx	2	1	1	....	....	20	7.38	....
Side	40	13	6	1	9	245	90.41	....
Stem	....	2	....	....	....	6	2.21	....
Total	42	16	7	1	9	271	....	....
Second brood:								
Calyx	9	....	4	....	2	37	1.30	....
Side	297	176	67	52	131	2,777	97.54	....
Stem	13	4	....	....	1	33	1.16	....
Total	319	180	71	52	134	2,847	....	3,118

A study of the percentages of larvæ of the respective broods entering the calyx, side, and stem ends of the fruit for each plat, as shown in Table XXI, presents some points of interest. On all plats a greater percentage of larvæ of the first brood entered at the calyx than was true of larvæ of the second brood. Thus, on the unsprayed plat (I), 85.20 per cent of the first-brood larvæ entered at calyx as against 50.45 per cent of second-brood larvæ. On Plat II (demonstration) 20.95 per cent of first-brood larvæ entered at calyx end as compared with 0.52 per cent of second-brood larvæ, while on Plat III (one spray) 7.38 per cent of first-brood larvæ entered at calyx and 1.30 per cent of second-brood larvæ entered at this place.

Attention should also be called to the ratio of increase of larvæ between the first and second broods. On Plat I (unsprayed) for every larva of the first brood there were 1.82 second-brood larvæ, whereas on Plat II (demonstration) and Plat III (one spray) for each larva of the first brood there were 7.7 and 10.5, respectively, of the second brood.

Similar comparison may also be made from the data from Arkansas. Thus, on the unsprayed plat (V) for each first-brood larva there were 4.8 second-brood larvæ. On Plat III (one spray) for each larva of the first brood there were 105.6 larvæ of the second brood. Plat I (one-spray method) shows for each first-brood larva 121.5 second-brood larvæ.

To show the comparative efficiency of the demonstation and one-spray treatments in preventing infestation at calyx, side, and stem, Table XXII is presented.

TABLE XXII.—*Efficiency of the one-spray and demonstration treatments as shown by the percentage of wormy apples. Saugatuck, Mich., 1909.*

Plat No.	Percentage of wormy apples.[a]				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		
I. Unsprayed	13.98	7.67	0.62	22.20	8,409	37,875
II. Demonstration	.09	2.92	.01	2.33	998	42,818
III. Onespray	.13	7.05	.09	6.36	2,738	42,867

[a] Each entrance was counted in determining the percentages for calyx, side, and stem, so that the sum of these percentages exceeds the total percentage of wormy fruit.

It is here seen that the two methods of spraying were about equally effective in preventing entrance at the calyx, and that the one-spray method had practically no effect upon side entrance. The demonstration treatment saved a total of 4.03 per cent of the crop more than the one-spray, practically all of this saving being due to the prevention of side entrance. But, as in all the other experiments, the demonstration treatment failed to reduce side entrance to anything like the same degree that calyx entrance was prevented.

THE PLUM CURCULIO.

The effects of the applications of sprays on the plum curculio in the E. H. House orchard are shown in Table XXIII.

TABLE XXIII.—*Injury by the plum curculio for entire season, Plats I, II, and III. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

	Number of punctured and sound apples, etc., per tree in each plat.						
	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.
No. punctures	1,452	422	506	505	1,078	756	141
No. fruit punctured	866	214	220	241	480	372	56
No. sound fruit	3,793	5,571	3,332	1,265	2,271	3,511	2,573
No. fruit	4,659	5,785	3,552	1,506	2,751	3,883	2,629
Per cent free from injury	81.41	96.30	93.81	83.99	82.55	90.42	97.87

TABLE XXIII.—*Injury by the plum curculio for entire season, Plats I, II, and III. Saugatuck, Mich., 1909*—Continued.

PLAT I. UNSPRAYED—Continued.

	Number of punctured and sound apples, etc., per tree in each plat.						Total per cent fruit free from injury.
	Tree 16.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	
No. punctures	1,108	883	530	1,265	1,197	9,843	....
No. fruit punctured	454	426	329	644	462	4,764	....
No. sound fruit	2,361	2,857	1,351	2,718	1,508	33,111	....
No. fruit	2,815	3,283	1,680	3,362	1,970	37,875	....
Per cent free from injury	83.87	86.96	80.42	80.85	76.55	....	87.42

PLAT II. DEMONSTRATION.

	Number of punctured and sound apples, etc., per tree in each plat.						
	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.
No. punctures	24	37	32	128	169	12	102
No. fruit punctured	11	13	15	60	61	5	62
No. sound fruit	1,614	1,752	2,145	1,790	5,658	4,017	5,734
No. fruit	1,625	1,765	2,160	1,850	5,719	4,022	5,796
Per cent free from injury	99.38	99.26	99.31	96.76	98.93	99.88	98.93

	Number of punctured and sound apples, etc., per tree in each plat.						Total per cent fruit free from injury.
	Tree 118.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	
No. punctures	112	89	139	398	10	1,252	....
No. fruit punctured	32	50	58	153	3	523	....
No. sound fruit	5,181	4,377	4,240	4,070	1,717	42,295	....
No. fruit	5,213	4,427	4,298	4,223	1,720	42,818	....
Per cent free from injury	99.39	98.87	98.65	96.38	99.83	....	98.77

PLAT III. ONE SPRAY.

	Number of punctured and sound apples, etc., per tree in each plat.						
	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.
No. punctures	1,015	278	108	198	64	67	45
No. fruit punctured	374	117	35	85	30	33	19
No. sound fruit	3,239	4,588	3,422	3,011	2,867	3,518	3,105
No. fruit	3,613	4,705	3,457	3,096	2,897	3,551	3,124
Per cent free from injury	89.92	97.51	98.99	97.25	98.96	99.07	99.39

	Number of punctured and sound apples, etc., per tree in each plat.						Total per cent fruit free from injury.
	Tree 244.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	
No. punctures	228	255	238	194	42	143	2,875	....
No. fruit punctured	65	102	91	43	20	40	1,054	....
No. sound fruit	4,494	4,239	2,817	3,400	1,118	1,995	41,813	....
No. fruit	4,559	4,341	2,908	3,443	1,138	2,035	42,867	....
Per cent free from injury	98.57	97.65	96.87	98.75	98.24	98.03	....	97.54

The plum curculio, it will also be noted, was not especially destructive at Saugatuck, Mich., during the season of 1909, the unsprayed trees showing 87.42 per cent of fruit free from injury. Nevertheless the demonstration and one-spray plats show a fair benefit, but the difference in the amount of fruit free from injury between these two plats, namely, 1.23 per cent, is not important.

SUMMARY STATEMENT OF RESULTS.

For the purpose of more ready comparison, the percentages of fruit free from codling-moth and plum-curculio injury on the one-spray, demonstration, and unsprayed plats, from the several localities, are tabulated in Table XXIV. The average percentage of fruit free from these insects for the four orchards gives for the one-spray method 91.46 per cent as against 96.57 per cent for the demonstration treatment, a gain in favor of the latter of 5.11 per cent. Comparing the final average of percentage of fruit free from the plum curculio, there is seen to be a gain in favor of the demonstration treatment of 6.27 per cent.

TABLE XXIV.—*Percentages of fruit free from injury by the codling moth and plum curculio on one-spray, demonstration, and unsprayed plats in Arkansas, Virginia, and Michigan, in 1909.*

Locality.	Codling moth.			Plum curculio.		
	One spray.	Demonstration.	Unsprayed.	One spray.	Demonstration.	Unsprayed.
Siloam Springs, Ark.	92.76	98.12	66.74	86.34	82.88	8.85
Crozet, Va.	84.07	94.13	53.02	73.93	86.89	54.02
Mount Jackson, Va.	91.68	92.74	54.00	57.90	40.82	27.23
Saugatuck, Mich.	93.61	97.66	77.79	97.54	98.77	87.42
Average of four localities	91.46	96.57	65.14	77.10	83.37	49.17

Table XXV presents in comparison the effect of treatments for the four orchards in reducing the number of wormy apples. The table shows, besides the total efficiency, the protection afforded to each of the different parts of the apple. From the averages of the four localities it will be seen that approximately two-thirds of the total larvæ on the unsprayed plat entered through the calyx, while on the sprayed plats over three-fourths of the worms entered the fruit by way of the side. This shows the very much greater efficiency of the poison in the calyx than of that on the side of the fruit and emphasizes the twofold advantage of a thorough poisoning of the calyx, as there it is that the spray gives the greatest protection against the greatest number of larvæ. A comparison of the effects of the one-spray and demonstration treatments on the percentage of apples wormy at the calyx shows about an equal degree of protection by the two methods, the average for the demonstration treatment being slightly the better. As to side entrance, the one-spray gave little improvement over the unsprayed condition, while the demonstration showed a considerable reduction. Both methods were effective in reducing entrance at the stem end, the demonstration somewhat the more so.

TABLE XXV.—*Efficiency of the one-spray and demonstration treatments, as shown by the percentages of wormy apples, Arkansas, Virginia, and Michigan, 1909.*

Locality.	Percentage of wormy apples.											
	Calyx.			Side.			Stem.			Total.		
	One-spray.	Demonstration.	Unsprayed.	One-spray.	Demonstration.	Unsprayed.	One-spray.	Demonstration.	Unsprayed.	One-spray.	Demonstration.	Unsprayed.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Siloam Springs, Ark	1.18	1.03	26.85	5.54	0.79	5.36	0.64	0.20	1.46	7.24	1.88	33.26
Crozet, Va	.73	.45	23.67	14.28	5.02	17.82	.92	.40	5.49	15.93	5.87	46.98
Mount Jackson, Va	.75	.99	35.71	6.46	5.61	7.48	1.11	.66	2.81	8.32	7.26	46.00
Saugatuck, Mich.[a]	.13	.09	13.98	7.05	2.92	7.67	.09	.01	.62	6.36	2.33	22.20
Average	.68	.57	23.85	7.64	2.87	8.92	.59	.18	2.21	8.55	3.42	34.86

[a] The figures under calyx, side, and stem for Saugatuck are based on the number of entrance holes instead of the number of apples entered.

CONCLUSIONS.

From the data presented, covering one season's work in three States, it appears that very satisfactory results may be obtained by the one-spray method, in so far as the control of the codling moth and plum curculio is concerned, although further experimentation will be necessary before final conclusions can be reached. Sight must not be lost, however, of the fact of the necessity, under eastern conditions, of making applications of Bordeaux mixture or other fungicide for the control of fungous diseases; so that in effect the one-spray method under present practices can not be recommended to orchardists in regions where fungous troubles, such as apple scab, apple fruit blotch, bitter rot, and leaf-spot affections require treatment.

The results, however, show the great importance of very thorough spraying to fill the calyx cups with poison. The efficiency of the spray at this point is much greater than at any other part of the apple. This, taken in connection with the fact that the majority of the larvæ seek the calyx as a point of entrance, makes the filling of the calyx of prime importance. Although the importance of accomplishing this has long been recognized by entomologists and fruit growers, it would appear that this work has not been done with sufficient thoroughness in the past, and eastern apple growers could certainly with great profit give more attention to thoroughness in the first spraying for the codling moth, immediately after the falling of the petals. The russeting of the fruit following such drenching applications of Bordeaux mixture, in which the arsenical has been generally applied, may doubtless be avoided by the substitution as a fungicide of dilute or self-boiled lime-sulphur wash, as shown to be feasible by Mr. W. M. Scott, of the Bureau of Plant Industry.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

TESTS OF SPRAYS AGAINST THE EUROPEAN FRUIT LECANIUM AND THE EUROPEAN PEAR SCALE.

By P. R. Jones,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

Attention appears to have been first called in California to the brown apricot scale by Mr. Alex. Craw[a] in 1891, at which time the insect was described by him under the name *Lecanium armeniacum.* The investigations of Mr. J. G. Sanders[b] while an agent of this Bureau, however, have unmistakably shown that the brown apricot scale of California is identical with *Lecanium corni* Bouché, known in Europe since 1844, which Mr. Sanders has appropriately named "the European fruit Lecanium."

The European pear scale (*Epidiaspis pyricola* Del Guer.) was first recorded as occurring in the United States by Prof. J. H. Comstock[c] in 1883, from Sacramento, Cal., under the preoccupied name *Diaspis ostreæformis.* Since their introduction these two scale pests have been the subject of considerable attention on account of their injuries, and at the present time in the Santa Clara Valley are by far the most important scale insects with which orchardists have to contend. The European fruit Lecanium is now especially abundant and the copious honeydew excreted by the scales upon the leaves and fruit, with the accompanying sooty fungus, leaves the fruit in an unsightly condition for market.

In connection with other work in the deciduous fruit insect investigations of the Bureau of Entomology, carried on at the laboratory at San Jose, Cal., experiments have been made to determine an effective treatment for both of these insects, with the results recorded in the following pages. The work during 1908 was carried out by Messrs. Dudley Moulton and Chas. T. Paine.

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[a] Rept. Cal. State Bd. Hort., p. 12, 1891.

[b] Journ. Econ. Ent., vol. 2, p. 443, 1909.

[c] 2d Rept. Ent. Dept. Cornell Univ., p. 94, 1883.

THE EUROPEAN FRUIT LECANIUM.

(*Lecanium corni* Bouché.)

APPEARANCE OF THE INSECT.

The insect heretofore generally known as the brown apricot scale belongs to the subfamily of scale insects, the Lecaniinæ, being naked but with hardened derm, and differs from the San Jose scale and European pear scale in that the horny covering of the full grown scale is a part of the body of the insect, while in the case of the other species mentioned the body is protected by a waxy covering made up from secretions and the molted skins of the larvæ.

The adult female of the European fruit Lecanium is about one-eighth to three-sixteenths of an inch long, three-thirty-seconds to one-eighth of an inch wide, and about one-eighth of an inch high, yellowish in color, marked with black. The older scales are shiny, oval, convex, and often covered with a mealy pruinose deposit (see Pl. XII, fig. 1).

PLAN OF WORK AND METHOD OF ASCERTAINING RESULTS.

In the winter of 1909 an infested orchard near San Jose, Cal., was selected and divided into 9 different plats of 14 trees each. Eight plats were used for trying out various sprays, and the ninth plat was left unsprayed for a check.

It was planned to examine a number of twigs at intervals of two days, two weeks, five weeks, three months, and ten months from date of spraying for proportion of live and dead scales; also, to take into account the action of the different washes on the trees and to examine the fruit as to freedom from the sooty fungus. The effect of the sprays upon the growth of lichens on the trunk and limbs was also to be noted. Such a number of examinations was considered necessary as some of the sprays were immediate in their action while others acted over a longer period.

APPLICATION OF SPRAYS.

All of the plats were treated February 18 with the sprays indicated below, using a single bent-disk nozzle (with one-eighth inch hole in disk) on each rod, the pressure being maintained at about 200 pounds by means of a gasoline-power outfit. At this pressure the lichens were thoroughly soaked. From 4 to 5 gallons of liquid were used per tree and the work was very thoroughly done.

SPRAYS USED AND METHOD OF PREPARATION.

Plat 1, 6 per cent distillate-oil emulsion.—This was made after the formula given in Bulletin 80, Part IV, Bureau of Entomology. A concentrated emulsion was made by dissolving 30 pounds of fish-

FIG. 1.—THE EUROPEAN FRUIT LECANIUM (LECANIUM CORNI BOUCHÉ) ON PECAN. (ORIGINAL.)

FIG. 2.—THE EUROPEAN PEAR SCALE (EPIDIASPIS PYRICOLA DEL GUER.) ON PEAR. (ORIGINAL.)

oil soap in 12 gallons of hot water and pouring the mixture into the spray tank with 20 gallons of distillate oil (28° Baumé). The mixture was then thoroughly agitated and run through the nozzles into a barrel at about 150 to 180 pounds pressure, giving a thick, creamy emulsion of about 55 per cent strength of oil. A powerful agitation, such as obtained by driving the liquid through nozzles or the relief valve at a high pressure, seems to be the most important factor in obtaining a stable emulsion. The formula used for the stock emulsion was:

Hot water	gallons..	12
Fish-oil soap	pounds..	30
Distillate oil (28° Baumé)	gallons..	20

The fish-oil soap was made as follows:

Water	gallons..	6
Lye	pounds..	2
Fish oil	gallons..	1½

The soap ingredients were boiled for about two hours and gave about 40 pounds of soap.

The 6 per cent distillate emulsion was made by taking about 5½ gallons of the concentrated emulsion and 44½ gallons of water. One pound of caustic soda was used to soften the water.

Plat 2, 5 per cent distillate-oil emulsion and caustic soda.—This was prepared by using 4½ gallons of the concentrated or stock emulsion, 5 pounds of caustic soda, and 45½ gallons of water to make 50 gallons of spray.

Plat 3, 6 per cent distillate-oil mechanical emulsion.—Made by using 3 gallons of distillate oil (28° Baumé), 1 pound of caustic soda, and 47 gallons of water to make 50 gallons of the liquid. This was agitated violently for about five minutes before being applied.

Plat 4, caustic soda.—Six pounds of caustic soda were used to 50 gallons of water.

Plat 5, 12 per cent crude-oil emulsion.—The formula used for this emulsion was—

Fish-oil soap	pounds..	5
Lye	do....	1
Crude oil	gallons..	6
Water	do....	43

This formula makes 50 gallons of liquid. The soap was dissolved in about 10 gallons of hot water; the soap water was then poured into the tank and the rest of the 43 gallons added; then the 1 pound of lye was added and the crude oil poured in slowly while the mixture was being agitated. *More water should never be added after the oil has been poured in.* The crude oil used was pure "Coalinga special" crude petroleum 16° to 22° Baumé, with an asphalt base.

Plat 6, resin-soda wash.—The following formula was used:

Resin . . . . pounds . .	10
Caustic soda . . . . do	3
Fish oil . . . . do	1½
Water . . . . gallons . .	50

The resin was broken into small lumps and together with the caustic soda placed in a kettle with 10 gallons of water. The mixture was then boiled for about half an hour, and while boiling 1½ pounds of fish oil were added; it was then poured into the tank and diluted with sufficient water to make 50 gallons of the wash.

Plat 7, commercial lime-sulphur solution (1–8).—Six and one-fourth gallons of the concentrated lime-sulphur solution and 43¾ gallons of water were used to make 50 gallons of spray.

Plat 8, borax.—Ten pounds of borax were used in 50 gallons of water.

Plat 9.—For purposes of comparison this plat was left unsprayed.

The respective treatments and results of same are shown in the following table:

TABLE I.—*Results of spraying for the European fruit Lecanium, San Jose, Cal., 1909.*

Plat No.	Treatment.	Date sprays applied.	Number trees sprayed.	First examination, Feb. 22, 1909.			Second examination, Mar. 6, 1909.		
				Number scales examined.	Number dead scales.	Percentage of dead scales.	Number scales examined.	Number dead scales.	Percentage of dead scales.
1	Distillate-oil emulsion	Feb. 18	14	305	304	99	926	896	96
2	Distillate-oil emulsion and caustic soda	. . do	14	428	426	99	647	640	97
3	Distillate-oil emulsion, mechanical mixture	. . do	14	467	465	99	216	118	54
4	Caustic soda	. . do	14	100	98	98	194	179	92
5	Crude-oil emulsion	. . do	14	90	90	100	122	78	64
6	Resin wash	. . do	14	180	180	100	30	21	70
7	Commercial lime-sulphur wash No. 1	. . do	14	400	400	100	252	17	7
8	Borax	. . do	14	200	200	100	64	28	44
9	Check	. . do	14	325	14	4	739	71	9

Plat No.	Treatment.	Third examination, Mar. 26, 1909.			Fourth examinaton, July 1, 1909.	Fifth examination, Dec. 13, 1909.
		Number scales examined.	Number dead scales.	Percentage of dead scales.		
1	Distillate-oil emulsion	290	290	100	Scales all dead; lichens dead.	Scales all dead; lichens dead.
2	Distillate-oil emulsion and caustic soda.	234	234	100	. . . . do	Do.
3	Distillate-oil emulsion, mechanical mixture.	219	219	100	. . . . do	Do.
4	Caustic soda	65	61	94	. . . . do	Do.
5	Crude-oil emulsion	94	94	100	. . . . do	Do.
6	Resin wash	65	54	83	A few live scales	Do.
7	Commercial lime-sulphur wash No. 1.	248	44	15	A number of live scales; lichens dead.	A number of live scales; lichens dead.
8	Borax	107	31	29	. . . . do	Do.
9	Check	142	24	17	Scales nearly all alive; lichens flourishing.	Scales nearly all alive; lichens flourishing.

RESULTS.

It will be seen from Table I that nearly all of the washes showed lower percentages of dead scales at the time of the second examination than at the first, third, fourth, and fifth examinations. The first five washes gave excellent results in the percentage of scales killed, and cleaned the trees from lichens.

Lime-sulphur wash and borax gave apparently excellent results upon the first examination, but later examinations proved these washes to be of little value, and the trees at the end of the season appeared little better than the unsprayed trees.

The fruit (12 tons) from the 8 sprayed blocks was free from the smut fungus, while that from the unsprayed trees was quite black in appearance. Caustic soda, borax, lime-sulphur, and the resin wash were all caustic and immediate in their action on the insects. The distillate sprays were prompt in their action, but not so much so as the former. The crude-petroleum sprays gave more of a smothering effect, and were slower, their action extending over a long period.

None of the washes injured the trees seriously, but the caustic soda, resin, lime-sulphur, and borax sprays blackened the buds and hardened the bark to some extent.

The distillate and crude-oil sprays did not injure the buds or the bark of the trees in the least, although some of the buds were very far advanced at the time of application.

It was noted during the summer that the distillate and crude-oil emulsions seemed to possess fungicidal properties. On sprayed apricots and prunes, the foliage was dark and healthy and of much better color than on the unsprayed blocks.

THE EUROPEAN PEAR SCALE.

(*Epidiaspis pyricola* Del Guer.)

APPEARANCE OF INSECT AND EXTENT OF INJURY.[a]

The European fruit scale, or, as it is commonly known in California, the Italian pear scale, closely resembles to the naked eye the San Jose scale (*Aspidiotus perniciosus* Comst.), but can be readily distinguished from this species by the form of the male scale which is a great deal longer and carinated. (See Pl. XII, fig. 2.)

Furthermore, they can be separated by the manner of working. The European pear scale, in California, so far as the writer has observed,

[a] Comparatively little has been written in an economic way concerning this insect, either in this country or in Europe. The writer has been unable to find an account of its life history; probably because it has never proved so serious as some of the other scales injurious to fruit trees. Attention, however, is called to an article on the synonymy of the species by C. L. Marlatt in Entomological News, November, 1900, p. 590.

works only under cover of the lichens on the trunk and larger limbs, and apparently does not work on the twigs or younger branches as does the San Jose scale. While the European pear scale is not so serious a pest to fruit trees as is the San Jose scale, nevertheless its manner of working under lichens causes it to be neglected by fruit growers until the trees are badly infested, with consequent loss in vitality.

SPRAYING EXPERIMENTS IN 1908.

PLAN OF WORK AND MANNER OF APPLICATION.

An orchard badly infested with the European pear scale (see Pl. XIII) was selected in February, 1908, and divided into 16 plats of 6 to 16 trees each. It was planned to examine a large number of scales in the laboratory from the treated trees of each plat, and a like number from the unsprayed, or check, trees, and also to make field examinations as to the effect of the sprays on the scales, on the lichens, and on the trees.

The applications of sprays were made February 18, 19, and 20 on plats 1 to 12; and March 3, on plats 13 to 16. A strong hand-pump tank outfit and also a barrel pump were used. No pressure gauge was on the pumps, but pressure was probably not more than 60 to 75 pounds. Vermorel nozzles were used.

SPRAYS USED AND METHOD OF PREPARATION.

Plat 1, lime-sulphur wash.—This was made after the same formula described for the European fruit Lecanium.

Plat 2, commercial lime-sulphur solution No. 1.—The stock solution was used at the rate of 1 part to 9 parts of water.

Plat 3, commercial lime-sulphur solution No. 2.—This spray, of different brand, was used at same strength as preceding.

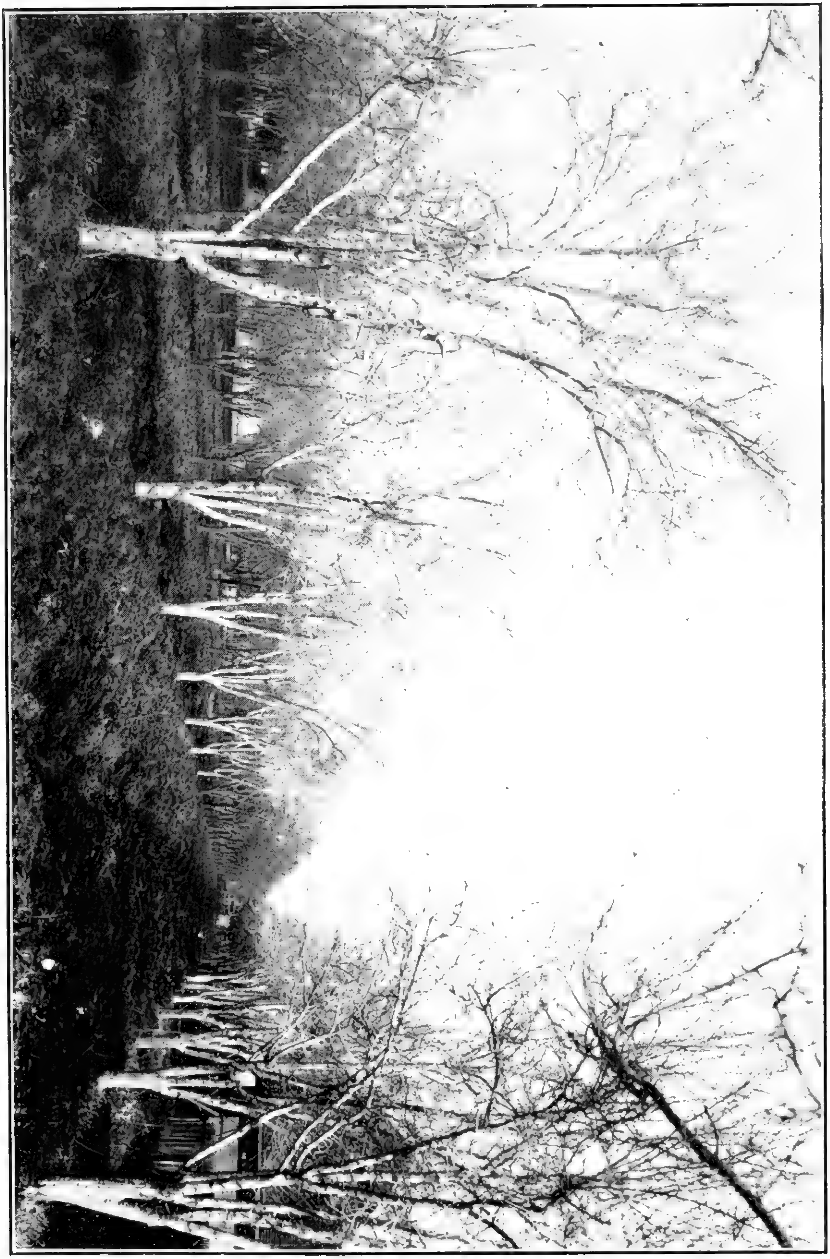
Plat 4, commercial 4 per cent distillate-oil emulsion.—This was used as follows:

Distillate-oil emulsion	gallons	$3\frac{1}{2}$
Caustic soda	pound	$\frac{3}{4}$
Water	gallons	50

Plat 5a, home-made 10 per cent distillate-oil emulsion.—This was made according to the following formula:

Boiling water	gallons	5
Fish-oil soap	pounds	2
Caustic soda	do	$\frac{3}{4}$
Distillate (28° Baumé)	gallons	5

When the water started to boil, the caustic soda was added; then the soap, and finally the oil. The whole mixture was then forced through a pump to emulsify it; it was then poured into the barrel and necessary water (40 gallons) to make 50 gallons of the spray was added.



VIEW OF PRUNE ORCHARD USED IN EXPERIMENTS AGAINST THE EUROPEAN PEAR SCALE. (ORIGINAL.)

A perfect emulsion was not formed, as some of the oil came to the top.

Plat 5b, 10 per cent distillate-oil emulsion.—This was made as follows:

Boiling water	gallons..	5
Fish-oil soap	pounds..	1½
Distillate (28° Baumé)	gallons..	5

Water (40 gallons) was added to make 50 gallons of the mixture. The emulsion was imperfect.

Plat 6, creosote-oil emulsion.—This is a commercial preparation and recommended to be used at the rate of 1 part to 20 parts of water, but was used 3 parts to 20 of water.

Plat 7a, home-made 10 per cent creosote-oil emulsion.—The following formula was used:

Boiling water	gallons..	5
Fish-oil soap	pounds..	2
Caustic soda	do....	2
Creosote oil	gallons..	5

The caustic soda, soap, and oil were added in turn after the water started to boil, and the mixture was forced through the pump to emulsify it. Water (40 gallons) was then added to make 50 gallons of wash.

Plat 7b, 5 per cent creosote-oil emulsion.—This was made in the same manner as for plat 7*a*, except that 100 gallons of spray were made.

Plat 8, commercial carbolic emulsion (distillate).—The following formula was used:

Emulsion	gallons..	5
Water	do....	40

Plat 9, 10 per cent crude-oil emulsion.—This was made with the ingredients proportioned as follows:

Boiling water	gallons..	5
Caustic soda	pound..	¼
Fish-oil soap	pounds..	4
Crude oil (12° to 14° Baumé)	gallons..	5

The caustic soda, soap, and oil were added to the water, in turn, as soon as it had started to boil. The mixture was then forced through the pump twice to emulsify it. Water (40 gallons) to make 50 gallons of wash was then added. The emulsion was not perfect, as some free oil came to the top.

Plat 10, caustic soda.—The following formula was used:

Water	gallons..	50
Caustic soda	pounds..	4

Plat 11a, 12 per cent crude-oil emulsion.—The formula was as follows:

Boiling water	gallons	10
Fish-oil soap	pounds	2½
Lye	do	½
Crude oil (16° to 22° Baumé)	gallons	3

The soap and lye were dissolved in the water, which was then placed in a barrel; 22 gallons of water were then added and the oil slowly poured in, and the mixture was thoroughly stirred. A very good emulsion resulted.

Plat 11b, 12 per cent crude-oil emulsion.—Same as for plat 11*a*, except that a "kerosene soap" was used.

Plat 11c, 12 per cent crude-oil emulsion.—Same as 11*a*, except that a 14° Baumé crude oil was used.

Plat 11d, 12 per cent crude-oil emulsion.—Same as 11*a*, except that a 12° to 14° Baumé crude oil was used.

None of the emulsions for plat 11 was forced through the pumps; but, on the other hand, no water was added to the mixture after the oil had been poured in. It seems to be essential, in order to keep free oil from coming to the top, that this be avoided. A good emulsion resulted in each case. The difference in gravity did not seem to make much difference in the emulsions, but the 16° to 22° Baumé, which was a "Coalinga special," appeared to give the best emulsion. All of the crude oils used contained an asphalt base.

RESULTS.

The results of the several sprays are given in Table II.

TABLE II.—*Results of spraying for the European pear scale, San Jose, Cal., 1908.*

Plat No.	Treatment.	Date sprays applied.	Number trees sprayed.	First examination, Mar. 3, 1908.		
				Number scales examined.	Number scales dead.	Percentage of dead scales.
1	Lime-sulphur (homemade)	Feb. 18	16	1,172	1,000	85
2	Commercial lime-sulphur, No. 1	...do...	9	547	51	9
3	Commercial lime-sulphur, No. 2	...do...	13	838	581	69
4	Commercial distillate-oil emulsion	...do...	13	926	280	30
5*a*	Distillate-oil emulsion (homemade)	Feb. 19	7	834	285	34
5*b*	....do	...do...	8	1,042	364	34
6	Commercial creosote-oil emulsion	...do...	11	664	174	26
7*a*	Creosote-oil emulsion (homemade)	Feb. 20	8	995	424	42
7*b*	....do	...do...	11	854	780	91
8	Commercial carbolic-distillate emulsion	...do...	13	789	689	87
9	Crude-oil emulsion	...do...	12	1,177	480	40
10	Caustic soda	...do...	6	905	632	64
11*a*	Crude-oil emulsion	Mar. 3	6	....	....	....
11*b*	....do	...do...	6	....	....	....
11*c*	....do	...do...	6	....	....	....
11*d*	....do	...do...	6	....	....	....

TABLE II.—*Results of spraying for the European pear scale, San Jose, Cal., 1908*—Con.

Plat No.	Treatment.	Second examination, Mar. 21, 1908. Number scales examined.	Number scales dead.	Percentage of dead scales.	Remarks.	Third examination, Dec. 17, 1908.
1	Lime-sulphur (homemade).	1,000	828	82	....	Many scales living; lichens mostly dead.
2	Commercial lime-sulphur, No. 1.	492	51	10	....	Many scales living; only larger lichens dead.
3	Commercial lime-sulphur, No. 2.	838	581	70	Scale killed better where there is heavy incrustation.	Do.
4	Commercial distillate-oil emulsion.	646	280	43	Lichens not all killed..	Many scales living; no lichens killed.
5*a*	Distillate oil emulsion (homemade).	549	285	52	.....do..........	Do.
5*b*	.....do..........	678	364	53	.....do..........	Do.
6	Commercial creosote-oil emulsion.	490	174	35	.....do..........	Many scales living; lichens mostly living.
7*a*	Creosote-oil emulsion (homemade).	571	424	74	Lichens all killed; bark hard and injured.	Many scales living; lichens mostly dead.
7*b*	.....do..........	854	780	91	Lichens all killed......	Do.
8	Commercial carbolic-distillate emulsion.	789	689	87	.....do..........	Do.
9	Crude-oil emulsion.....	697	480	69	.....do..........	Most all scales dead; lichens mostly all dead.
10	Caustic soda..........	905	632	64	Lichens all killed; bark hard.	Most all scales living; lichens mostly all dead.
11*a*	Crude-oil emulsion.....	(*a*)	(*b*)	100	.....do..........	Most all scales dead; lichens mostly all dead.
11*b*	.....do..........	(*a*)	(*b*)	100	.....do..........	Do.
11*c*	.....do..........	(*a*)	(*b*)	100	.....do..........	Do.
11*d*	.....do..........	(*a*)	(*c*)	90	.....do..........	Do.
Check	Unsprayed..........	736	84	11	....	....

[a] Large number. [b] All. [c] Nearly all.

An examination of the table shows that at the end of the season only the crude-oil emulsions had proved adequate in killing all the scales and lichens. No injury to the trees was apparent except where the caustic soda and creosote-oil emulsion were used.

SPRAYING EXPERIMENTS IN 1909.

PLAN OF WORK AND MANNER OF APPLICATION.

A badly infested orchard other than the one used in 1908 was selected and divided into 6 different plats of 32 trees each. Four examinations of infested material were made in the laboratory and in the field at intervals of three days, three weeks, six weeks, and eight months, respectively, after the applications. A large number of scales was examined from each of the six plats and the check plat.

The applications were made March 1, 1909, with a strong power outfit, using two leads of hose with 12-foot bamboo rods and single-crook nozzles, with $\frac{1}{8}$-inch apertures. A pressure of 200 to 240 pounds was maintained, and the trees were given a very thorough treatment.

SPRAYS USED AND METHOD OF PREPARATION.

Plat 1, 6 per cent distillate oil (mechanical mixture).—This was prepared as follows:

Water	gallons..	90
Caustic soda	pounds..	2
Distillate oil (28° Baumé)	gallons..	6

The water was poured into the tank; then the caustic soda was added to soften the water, and the oil slowly poured in while the water was being violently agitated. The mixture was applied immediately.

Plat 2, caustic soda.—The formula was as follows:

Water	gallons..	100
Caustic soda	pounds..	16

Plat 3, crude-oil emulsion.—This was prepared as follows:

Water	gallons..	86
Fish-oil soap	pounds..	10
Lye	do....	2
Crude oil (16° to 22° Baumé)	gallons..	12

About 20 gallons of the water were heated, and when this began to boil the dissolved soap and then the lye were added. This mixture was then removed to the tank, and the rest of the water (66 gallons) added, making 86 gallons in all. The spray pump engine was then started and the crude oil slowly poured into the tank, the mixture being violently agitated by the tank agitator. A perfect emulsion resulted.

Plat 4, commercial lime-sulphur solution, No. 1.—The formula was as follows:

Water	gallons..	100
Commercial lime-sulphur	do....	11

Plat 5, borax.—The formula was as follows:

Water	gallons..	100
Borax	pounds..	20

The borax was dissolved in 30 gallons of hot water and poured into the tank, and the rest of the water added.

Plat 6, well-cooked lime-sulphur wash.—The proportions of ingredients were as follows:

Lime	pounds..	30
Sulphur	do....	30
Water	gallons..	100

This wash was made in the same manner as previously described.

The results of tests in 1909 are given in Table III.

TABLE III.—*Results of spraying for the European pear scale, San Jose, Cal., 1909.*

Plat No.	Treatment.	Date sprays applied.	Number trees sprayed.	First examination, Mar. 3-4, 1909. Number scales examined.	Number scales dead.	Percentage of scales dead.	Second examination, Mar. 20, 1909. Number scales examined.	Number scales dead.	Percentage of scales dead.	Remarks.
1	Distillate-oil mechanical mixture.	Mar. 1	32	620	516	83	498	380	78	Lichens mostly alive.
2	Caustic soda	...do....	32	706	534	75	844	749	88	Do.
3	Crude-oil emulsion	...do....	32	344	297	86	599	393	65	Lichens all dead.
4	Commercial lime-sulphur, No. 1.	...do....	32	950	846	89	709	627	88	Lichens mostly dead.
5	Borax	...do....	32	407	361	88	1,029	1,003	97	Do.
6	Homemade lime-sulphur.	...do....	32	371	275	74	673	504	74	Lichens nearly all alive.
7	Check		....	941	541	56	685	341	49	Lichens flourishing.

Plat No.	Treatment.	Third examination, Apr. 16, 1909. Number scales examined.	Number scales dead.	Percentage of scales dead.	Fourth examination, Nov. 20, 1909. Number scales examined.	Number scales dead.	Percentage of scales dead.	Remarks.
1	Distillate-oil mechanical mixture.	805	789	98	759	757	100	Lichens mostly dead; bark soft.
2	Caustic soda	637	449	70	455	449	98	Lichens mostly dead; bark hard.
3	Crude-oil emulsion	648	613	94	207	207	100	Lichens mostly dead; bark soft.
4	Commercial lime-sulphur, No. 1.	536	411	76	659	624	93	Lichens mostly dead; bark slightly hardened.
5	Borax	640	609	95	452	449	99	Lichens mostly dead; bark hard.
6	Homemade lime-sulphur.	652	514	79	1,147	811	70	Lichens mostly dead; bark slightly hardened.
7	Check	372	133	35	939	96	10	Lichens flourishing.

RESULTS.

An examination of Table III shows that all of the sprays with the exception of the commercial lime-sulphur solution No. 1 and the well-cooked lime-sulphur washes proved very successful in killing the scale. All of them killed most of the lichens. The caustic-soda and borax treatments injured the trees to a certain extent and hardened the bark. In the case of the trees treated with distillate-oil emulsion and crude-oil emulsion the bark was normal and in good condition.

As noted previously, on the apricots the distillate-oil sprays as well as those from crude oil seemed to possess distinct fungicidal properties, as the foliage was as dark and healthy on these plats and remained on the trees as long as on the plats sprayed with commercial and cooked lime-sulphur washes.

A comparison of the results of 1908 and 1909 shows much in favor of the latter year, which should be attributed to the better method of application and of making the sprays. It appears essential for good results to use a power outfit at a high pressure and a coarse drenching spray to penetrate the lichens and the heavy scale incrustation. A power sprayer is especially useful in applying distillate-oil emulsion, crude-oil emulsion, and mechanical mixtures of either, as a hand outfit does not give sufficient agitation for a perfect emulsion.

The writer recently noticed several prune orchards which had been sprayed with a commercial distillate spray and caustic soda at 4 per cent strength; they were well cleaned of the scales and lichens.

COST OF SPRAYING.

Table IV shows the comparative cost of materials of the most important and efficient treatments. To get the total cost of spraying it will be necessary merely to add the cost of the labor, which is variable and was therefore not included. Usually 3 men and a team are required for spraying with a hand pump and the same number with a power outfit, adding an additional man and team where a supply wagon is used.

The number of trees that can be sprayed in a day is variable, depending upon the size of the trees, the availability of the water, and the efficiency of the labor. With medium-sized prune trees, from 800 to 1,000 trees is considered a good day's work with a power outfit and a supply tank.

Below is shown what the ingredients of the spray mixtures would cost the fruit grower in the vicinity of San Jose in barrel lots:

Lime (unslaked)	per barrel	$1.75
Sulphur (flour)	per 100 pounds	2.65
Caustic soda, in 120-pound cases	per pound	.05½
Borax, in 12-pound cases		1.40
Lye, in 48-pound cases		3.25
Fish oil, in barrel lots	per gallon	.35
Crude oil (12 to 24° Baumé), in 110-gallon drums		3.00
Distillate oil (28° Baumé), in 110-gallon drums	per gallon	.07–.09
Commercial lime-sulphur solution	per barrel	[a] 10.00
Commercial distillate-oil emulsion	do	[a] 7.50
Commercial distillate emulsion and caustic soda	do	[a] 9.95

A good fish-oil soap can be made at the following cost:

Lye, 2 pounds	$0.1354
Fish oil, 1½ gallons	.5250
Water, 6 gallons.	

This makes $0.6604 for 40 pounds of soap, or $0.0165 per pound.

The concentrated distillate-oil emulsion (55 per cent) will cost:

Hot water, 12 gallons.	
Fish-oil soap, 30 pounds	$0.495
Distillate oil (28° Baumé), 20 gallons	1.400
Total	1.895

This makes $1.895 for 36 gallons, or $0.0526 per gallon.

[a] About.

TABLE IV.—*Comparative cost of spray materials.*

Treatment.	Formula.		Cost of ingredients.	Cost per 100 gallons.	Cost per diluted gallon.	Cost per tree (prune).	Cost per tree (apricot).
	Article.	Quantity.					
6 per cent distillate oil (mechanical mixture).	Oil Caustic soda Water	6 gallons 2 pounds 94 gallons	$0.42 .11	$0.53	$0.0053	$0.0212	$0.0265
6 per cent distillate-oil emulsion.	Concentrated emulsion. Caustic soda Water	11 gallons 2 pounds 89 gallons	.5786 .11	.6886	.00688	.0275	.0344
5 per cent distillate-oil emulsion and caustic soda.	Concentrated emulsion. Caustic soda Water	9 gallons 10 pounds 91 gallons	.4734 .55	1.023	.0102	.0408	.0511
4 per cent commercial distillate-oil emulsion.	Emulsion Water	6⅔ gallons 92⅓ gallons	1.00	1.00	.01	.04	.05
4 per cent commercial distillate-oil emulsion and caustic soda.	Emulsion Water	6⅔ gallons 92⅓ gallons	1.326	1.326	.0132	.0528	.066
12 per cent crude-oil emulsion.	Oil Soap Lye Water	12 gallons 10 pounds 2 pounds 88 gallons	.3264 .0875 .1354	.5493	.0054	.0219	.0274
Resin-soda wash	Resin Caustic soda Fish oil Water	20 pounds 6 pounds 3 gallons 100 gallons	.55 .33 .1311	1.011	.0101	.0404	.0505
Commercial lime-sulphur No. 1 (1-8).	Concentrated solution. Water	11 gallons 88 gallons	2.20	2.20	.022	.088	.11
Home-made lime-sulphur.	Lime Sulphur Water	40 pounds 30 pounds 100 gallons	.35 .795	1.145	.0145	.058	.0725
Caustic soda	Caustic soda Water	12 pounds 100 gallons	.66	.66	.0066	.0264	.033
Borax	Borax Water	20 pounds 100 gallons	2.32	2.32	.0232	.0928	.116

SUMMARY.

Distillate-oil emulsion at 5 per cent and 6 per cent strengths, with and without caustic soda; crude-oil emulsion at 12 per cent strength; and resin-soda wash are effective in controlling the European fruit Lecanium and in cleaning up the trees from lichens and do not injure the trees when applied as a winter treatment.

Distillate-oil emulsion at 5 per cent and 6 per cent strengths, with and without caustic soda; distillate oil at 6 per cent strength (mechanical mixture); and crude-oil emulsion at 12 per cent strength are effective in controlling the European pear scale, destroy the lichens, and do not injure the trees when applied as a winter treatment.

Caustic-soda and creosote-oil emulsion sprays control both of these scales and destroy the lichens, but are injurious to the tree.

Lime-sulphur and borax sprays are not so efficient in controlling these scales, especially the European fruit Lecanium, as are the distillate-oil and crude-oil emulsions, and borax acts on the trees in the same way as does caustic soda.

Distillate-oil and crude-oil emulsions appear to have distinct fungicidal properties aside from their insecticidal value.

Distillate-oil emulsions at 6 per cent strength and crude-oil emulsion at 12 per cent strength, measured by their efficiency against scales and lichens, convenience of preparation and application, and cost, are the sprays best adapted for the European fruit Lecanium and the European pear scale.

The 6 per cent distillate-oil emulsion will cost about $2\frac{1}{2}$ cents for each prune tree and $3\frac{1}{2}$ cents for each apricot tree.

The 12 per cent crude-oil emulsion will cost about 2 cents for each prune tree and $2\frac{1}{2}$ cents for each apricot tree.

All sprays, to insure the best results, should be applied with a power outfit at a high pressure (180 to 200 pounds). A coarse, drenching spray applied with crook nozzles is preferable, and February is the best month in which to spray.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CODLING MOTH IN THE OZARKS.

BY

E. L. JENNE,

Engaged in Deciduous Fruit Insect Investigations.

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Deciduous Fruit Insect Investigations.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CODLING MOTH IN THE OZARKS.

By E. L. Jenne,
Engaged in Deciduous Fruit Insect Investigations.

In 1907 the Bureau of Entomology undertook some experimental and demonstration spraying for the control of the codling moth at Siloam Springs, Benton County, Arkansas. The work being largely investigation of remedies, only a few notes relating to the life history of the insect were secured. The following season a fuller line of rearing work was conducted at the same place, and the present account of the codling moth in that locality applies mainly to the season of 1908. Data for 1907 are introduced for comparison, where it is possible.

In 1908 the rearing work was conducted out of doors. Moths were confined in Riley rearing cages; larvæ were reared in fruit inclosed in paper bags on the trees, or in picked fruit in muslin-covered battery jars; and the pupal periods were observed in small vials.

SEASONAL HISTORY.

SPRING BROOD OF PUPÆ.[a]

Duration of the brood.—The earliest pupæ did not come under observation, but judging from the first emergence of moths and the length of the earliest observed spring pupal stages, pupation began in late February or early March.

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[a] The term "brood" is used in speaking of any single stage of the insect, and "generation" to include all the stages of the life cycle.

The pupæ and moths produced by the transformation of the wintering larvæ are sometimes termed "first-brood pupæ" and "first-brood moths." Here, however, the first generation is regarded as beginning with the first eggs of the season, and ending with the moths that develop therefrom. Where three generations of the insect occur, the adult stages are spoken of as moths of spring brood, moths of first brood, and moths of second brood. The adults of the third generation become the spring brood of moths for the succeeding year. The spring moths lay the first-brood eggs, the first-brood moths lay the second-brood eggs, and second-brood moths lay the third-brood eggs.

On March 24 there were taken, from rubbish on the ground under an outdoor apple bin at a vinegar factory, 6 pupæ and 130 larvæ. They were located in a damp place, shaded during the greater part of the day. Above, in crevices of the apple bin, were many cocoons, for the most part inaccessible, but those that could be examined showed a much larger proportion of pupæ.

On March 31 some timbers were pried from this bin and larvæ and pupæ were found in about equal numbers—122 larvæ and 112 pupæ. This bin was situated on the west side of the building and was built of 2 by 4 material, nailed, 1 inch apart, to large supporting timbers. The cocoons occurred between the scantlings and their supports. This should represent fairly normal conditions above ground. Even here pupæ would be found greatly in the majority under one scantling, while beneath an adjoining one nearly all cocoons might contain larvæ. This was evidently due to the fact that some of the pine scantlings were sapwood, which absorbs much moisture during rains. At the time of examination they were damp and soggy, though no rain had fallen for several days. Under these the proportion of pupæ was much smaller than under dry scantlings adjoining.

No empty pupal cases were found March 31, although one adult moth, evidently just emerged, was captured while sunning itself on the bin. On April 21 the bin was again examined, and there were found 79 larvæ, 114 pupæ, and 64 empty cases. This showed that about 70 per cent of the wintering larvæ had pupated up to that time. But even yet larvæ were in the majority in damp and shaded parts.

Nearly all of the larvæ collected on the above dates and kept out of doors in vials had pupated by May 12. Two belated individuals pupated May 19 and 20. This gives a probable time of 2½ months during which wintering larvæ transformed to pupæ. Apple trees bloomed about the middle of this period. The majority of the spring pupæ had given out adults by May 27, the two belated individuals emerging June 6 and 8. Thus there is a period of about 3 months during which spring pupæ were present—from the first of March until June.

Length of spring pupal stage.—Individual records were obtained of 131 spring pupæ, from larvæ collected at the out door apple bin. The material was kept out of doors in vials in a pasteboard box, under as nearly a normal temperature as possible. The length of the pupal stage steadily decreased with the advancement of the season. Doubtless a longer period would have been shown for the first pupæ of the season if they could have been observed.

The records of the spring pupal stages are given in Tables I and II, with a summary in Table III.

TABLE I.—*Length of pupal periods in spring brood of pupæ—from wintering larvæ collected March 31.*

Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.	Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.
			Days.				*Days.*
1	Apr. 1	May 1	30	43	Apr. 14	May 11	27
2	Apr. 2	Apr. 28	26	44	...do...	...do...	27
3	...do...	Apr. 30	28	45	...do...	...do...	27
4	...do...	May 3	31	46	Apr. 15	...do...	26
5	Apr. 4	May 1	27	47	...do...	...do...	26
6	Apr. 5	May 2	27	48	...do...	...do...	26
7	Apr. 6	May 3	27	49	...do...	...do...	26
8	...do...	May 4	28	50	...do...	...do...	26
9	Apr. 7	...do...	27	51	...do...	...do...	26
10	Apr. 8	...do...	26	52	...do...	May 12	27
11	...do...	May 5	27	53	Apr. 16	May 11	25
12	...do...	...do...	27	54	...do...	...do...	25
13	Apr. 9	...do...	26	55	...do...	...do...	25
14	Apr. 10	...do...	25	56	...do...	May 12	26
15	...do...	...do...	25	57	...do...	...do...	26
16	...do...	...do...	25	58	...do...	...do...	26
17	Apr. 11	...do...	24	59	...do...	...do...	26
18	...do...	...do...	24	60	...do...	...do...	26
19	...do...	...do...	24	61	Apr. 17	May 11	24
20	...do...	May 8	27	62	...do...	May 12	25
21	...do...	...do...	27	63	...do...	May 13	26
22	...do...	May 9	28	64	...do...	...do...	26
23	...do...	May 10	29	65	...do...	...do...	26
24	Apr. 12	May 9	27	66	...do...	May 14	27
25	...do...	May 10	28	67	Apr. 18	May 12	24
26	...do...	...do...	28	68	...do...	...do...	24
27	Apr. 13	May 9	26	69	...do...	May 13	25
28	...do...	...do...	26	70	...do...	May 14	26
29	...do...	May 10	27	71	...do...	...do...	26
30	...do...	...do...	27	72	...do...	May 15	27
31	...do...	...do...	27	73	Apr. 19	...do...	26
32	...do...	...do...	27	74	...do...	...do...	26
33	...do...	...do...	27	75	...do...	May 16	27
34	...do...	...do...	27	76	Apr. 20	May 15	25
35	...do...	...do...	27	77	...do...	May 16	26
36	Apr. 14	...do...	26	78	...do...	...do...	26
37	...do...	...do...	26	79	Apr. 21	May 15	24
38	...do...	...do...	26	80	...do...	May 16	25
39	...do...	...do...	26	81	Apr. 22	...do...	24
40	...do...	...do...	26	82	...do...	...do...	24
41	...do...	May 11	27	83	Apr. 23	May 17	24
42	...do...	...do...	27				

TABLE II.—*Length of pupal periods in spring brood of pupæ—from wintering larvæ collected April 21.*

Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.	Individual No.	Wintering larva pupated.	Moth emerged.	Length of pupal stage.
			Days.				*Days.*
1	Apr. 22	May 16	24	25	May 3	May 25	22
2	...do...	May 17	25	26	May 4	May 22	18
3	Apr. 23	May 19	26	27	...do...	...do...	18
4	Apr. 24	May 18	24	28	May 5	...do...	17
5	Apr. 25	...do...	23	29	...do...	...do...	17
6	...do...	...do...	23	30	...do...	...do...	17
7	...do...	...do...	23	31	...do...	...do...	17
8	...do...	...do...	23	32	...do...	...do...	17
9	Apr. 26	May 19	23	33	...do...	...do...	17
10	...do...	...do...	23	34	...do...	...do...	17
11	Apr. 27	...do...	22	35	...do...	May 23	18
12	Apr. 28	...do...	21	36	...do...	...do...	18
13	Apr. 30	May 20	20	37	May 6	May 22	16
14	May 1	...do...	19	38	...do...	May 23	17
15	...do...	...do...	19	39	May 8	...do...	15
16	...do...	...do...	19	40	...do...	...do...	15
17	...do...	May 21	20	41	...do...	...do...	15
18	May 3	May 20	17	42	May 10	...do...	13
19	...do...	May 21	18	43	May 11	May 25	14
20	...do...	...do...	18	44	May 12	...do...	13
21	...do...	...do...	18	45	...do...	May 27	15
22	...do...	...do...	18	46	May 13	May 26	13
23	...do...	...do...	18	47	May 19	June 8	20
24	...do...	May 22	19	48	May 20	June 6	17

TABLE III.—*Spring brood of pupæ—summary of pupal periods shown in Tables I and II.*

Wintering larvæ collected.	Number of individuals.	Maximum pupal life.	Minimum pupal life.	Average pupal life.
		Days.	*Days.*	*Days.*
March 31	83	31	24	26.2
April 21	48	26	13	18.5
Both lots	131	31	13	23.5

SPRING BROOD OF MOTHS.

Duration of emergence.—Emergence began out of doors March 31, on which date we captured a moth while collecting wintering material at the outdoor apple bin. As no empty pupal cases were found this may be considered the beginning of emergence. Ben Davis apple trees were in full bloom at this time. From wintering material collected March 31, moths began emerging April 9. Some probably would have issued earlier had not a large proportion of the pupæ been injured in collecting. On again examining the apple bin, on April 21, the numerous empty pupal cases indicated that about 25 per cent of the moths had issued, there being found 64 empty cases and 193 larvæ and pupæ. By May 27 all moths had emerged from collected wintering material except two belated individuals which issued June 6 and 8. The latter date coincides with the issuance of the first moth of the first brood. Briefly, the spring brood of moths issued during a period of 2 months, beginning with the date of full-bloom of apple trees (March 31).

The emergence of moths from collected wintering material is shown in Table IV.

TABLE IV.—*Emergence of spring brood of moths—summary of emergence records from wintering material collected March 24, March 31, and April 21.*

Date.	Number of moths emerging.	Date.	Number of moths emerging.	Date.	Number of moths emerging.	Date.	Number of moths emerging.	Date.	Number of moths emerging.
Apr. 9	1	Apr. 20	1	May 1	3	May 12	16	May 23	8
Apr. 10	2	Apr. 21	3	May 2	9	May 13	12	May 24	1
Apr. 11	0	Apr. 22	4	May 3	10	May 14	0	May 25	3
Apr. 12	0	Apr. 23	11	May 4	13	May 15	11	May 26	2
Apr. 13	1	Apr. 24	2	May 5	22	May 16	11	May 27	1
Apr. 14	0	Apr 25	4	May 6	2	May 17	8	June 6	1
Apr. 15	2	Apr. 26	0	May 7	0	May 18	7	June 8	1
Apr. 16	1	Apr. 27	0	May 8	3	May 19	5		
Apr. 17	2	Apr. 28	1	May 9	0	May 20	10		
Apr. 18	4	Apr. 29	2	May 10	27	May 21	6		
Apr. 19	1	Apr. 30	1	May 11	29	May 22	11		

The data given in Table IV are shown graphically in the accompanying curve, figure 1.

The above record is from 320 larvæ and 232 pupæ collected March 24, March 31, and April 21 from the outdoor apple bin. These 552 larvæ and pupæ produced 275 adults. A much larger number of pupæ than of larvæ were injured in collecting and failed to give out moths. This, together with the fact that 193 of the total number collected were taken after emergence had begun, would throw the maximum of emergence here shown considerably later than it should be. As before stated, about 25 per cent of the moths had emerged in the field, from cocoons above ground, by April 21.

In 1907 Mr. Dudley Moulton records the finding of a few empty pupal skins while collecting wintering material in an open packing shed April 27. This was 25 days after the apple blossoms had fallen, a period of cold weather occupying the interval. From material then collected moths continued to issue in the laboratory until June 1.

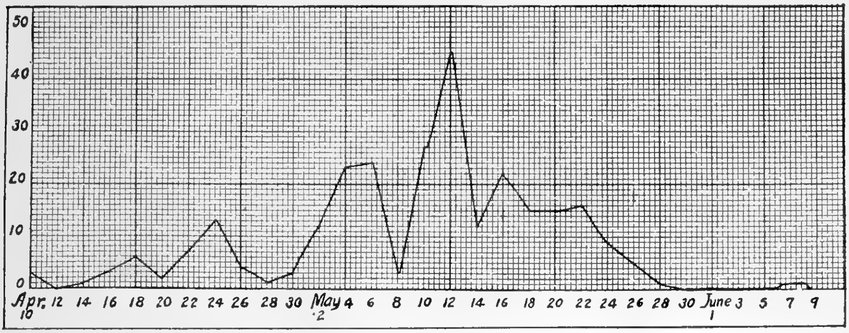

FIG. 1.—Curve showing emergence of spring brood of adults of codling moth (*Carpocapsa pomonella*) from collected wintering material.

Life of the moth.—Records of 28 spring-brood moths emerging April 13–23, and confined in a Riley rearing cage out of doors, show an average life of 10.5 days. Another lot of 35 moths that emerged April 25 to May 4 gives an average life of 9.1 days. The life of the moths is largely dependent on temperature. They are able to lay fertile eggs in 3 to 5 days after emergence, but during cold weather in spring or fall they remain torpid for long periods. Moths can be fed by putting into the cage a piece of raw cotton soaked in sirup or fruit juice. However, even without food, if a sufficient number of moths are confined together, eggs will be laid abundantly. Data on caged spring-brood moths are given in Tables V and VI. These moths issued from the wintering material collected March 24 and March 31.

TABLE V.—*Life of spring brood of moths—Cage I.*

Moths emerged and put into cage.		Moths died.		Average life of moths.	Eggs laid (at night).	
Date.	Number.	Date.	Number.		Date.	Number.
April 13	1	April 19	1		April 19	23
April 15	2	April 20	1		April 24	46
April 16	1	April 22	1		May 2	16
April 17	2	April 24	4			
April 18	4	April 28	2			
April 19	1	April 29	3			
April 20	1	April 30	5	10.5 days.		
April 21	3	May 1	1			
April 23	15	May 2	1			
		May 3	2			
Total	30	May 4	3			
		May 5	1			
		May 9	2			
		May 10	1			
		Escaped	2			

TABLE VI.—*Life of spring brood of moths—Cage II.*

Moths emerged and put into cage.		Moths died.		Average life of moths.	Eggs laid (at night).	
Date.	Number.	Date.	Number.		Date.	Number.
April 25	4	May 2	2		May 4	5
April 28	1	May 4	1		May 8	16
April 29	2	May 5	1		May 11	45
May 1	2	May 6	3			
May 2	9	May 7	1			
May 3	12	May 9	2			
May 4	10	May 10	5	9.1 days.		
		May 11	4			
Total	40	May 12	3			
		May 13	2			
		May 14	4			
		May 15	3			
		May 16	2			
		May 17	2			
		Escaped	5			

THE FIRST GENERATION.

FIRST-BROOD EGGS.

Period of oviposition.—Eggs were not laid in the rearing cages as early as in the field, because of the lack of a sufficient number of the earliest moths. Eggs collected in the field began to hatch April 27, which, from the earliest observed periods of incubation, would indicate that oviposition had commenced as early as April 7. Apple blossoms had nearly all fallen by April 7. Eggs were abundant in the orchard on April 27, 67 eggs being collected from the lower branches of 2 trees in the space of half an hour. Of these, 6 were empty shells, 2 showed the black head of the larva and hatched the same day, 36 showed the red ring, and 23 were undeveloped. Eggs continued abundant in the orchard during the early part of May.

The last unhatched eggs of the first brood were found May 27. Empty shells were numerous in the orchard at that time, but only 3 unhatched eggs were found, all of them in the "black-spot" stage. This date seems to be near the end of the first brood of eggs, and agrees with the issuing records of moths from collected wintering material, practically all moths having emerged by this time.

In 1907 the last of the first-brood eggs were obtained June 2, having been laid in a cage by the last moths to emerge from collected wintering material kept in the laboratory.

Place of oviposition.—Of 67 eggs collected in the orchard April 27, 53 occurred on the upper side of leaves, 13 on the back of leaves, and 1 on a twig. While bagging fruit on May 6 a careful examination for eggs was made on all the leaves, twigs, and fruit to be inclosed in the bags. There were 78 eggs or empty shells found, of which 76 were on the upper surface of leaves, 1 on a twig, and 1 on the side of the fruit. Since but few apples became wormy after being bagged, this represents nearly the whole number of eggs present on the parts examined. Some of the eggs were at a considerable distance from any fruit, but as a rule the moths seemed to have selected the fruit clusters, possibly only because the foliage there was denser than on isolated shoots.

In the cages eggs were placed indiscriminately on all parts of twigs, leaves, fruit, framework of cage, and on the glass panes, always, however, on the side of the cage from which most light came. Twigs placed in the middle or on the darker side of the cage were disregarded, the moths depositing their eggs on the side or bottom of the cage while struggling to fly out toward the light.

Fertility.—Practically all eggs observed were fertile, whether laid in cages or collected in the orchard. Often a few sterile eggs were deposited in the cages before oviposition proper began. When eggs were laid in considerable numbers they were all fertile.

Length of incubation period.—The egg stage was greatly lengthened by periods of cool weather such as are apt to occur in early spring. The first eggs obtained in cages were deposited the night of April 19. These were subjected to very cool weather, including frost, and gave a maximum period of 21 days, or an average of 19.6 days. Eggs deposited the night of April 24 experienced part of the same spell of cool weather, including frost, and required an average of 17 days to hatch. With the advent of warm weather the egg stage was rapidly shortened. Eggs deposited May 8 hatched in 8½ days, and the lot laid May 10 hatched in 7½ days. Undoubtedly the last eggs of the first brood would show the uniform period of 5 days required for second-brood and third-brood eggs laid during June, July, and August. In Table VII are shown the incubation records of first-brood eggs deposited in outdoor cages.

TABLE VII.—*First-brood eggs—incubation records of eggs laid in Cages I and II (recorded in Tables V and VI).*

Number of eggs.	When laid (night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
A. 21 EGGS LAID IN CAGE I.					
					Days.
2	Apr. 19	Apr. 27	May 4	May 6	17
5	...do.....	...do.....	May 5	May 8	19
11	...do.....	...do.....	...do.....	May 9	20
3	...do.....	...do.....	...do.....	May 10	21
B. 46 EGGS LAID IN CAGE I.					
1	Apr. 24	May 2	May 10	May 11	16
2	...do.....	...do.....	May 9	May 12	17
6	...do.....	...do.....	May 10	...do.....	17
30	...do.....	...do.....	May 11	...do.....	17
4	...do.....	May 3	...do.....	...do.....	17
1	...do.....	May 2	...do.....	May 13	18
1	...do.....	May 3	....	May 14	19
C. 16 EGGS LAID IN CAGE II.					
16	May 8	....	....	May 17 a. m.	8.5
D. 45 EGGS LAID IN CAGE II.					
45	May 10	....	....	May 17 p. m.–May 18 a. m.	7.5

FIRST-BROOD LARVÆ.

Period of hatching.—The date of the earliest hatching of larvæ can be put fairly accurately at about April 27 (3 weeks after petals had fallen), as on that day out of 67 eggs collected in the orchard only 6 were empty shells and 2 in the black-spot stage, hatching the same day. No wormy apples were found until May 4, the calyx lobes probably concealing their work for several days. Larvæ continued to enter the fruit in numbers during nearly the whole of May. The last of the brood probably entered during the first week of June, which is allowing 10 days from the time of the last observed unhatched egg in the orchard. The great majority of the first brood of larvæ entered the fruit during May.

Thus it will be seen that up to this time the different stages of the insect, instead of showing an increasing tendency to occupy a longer time, have actually become more compact. While it required about 2½ months for the wintering larvæ to pupate, the spring moths issued within a space of 2 months and the first brood of larvæ hatched in scarcely more than 45 days. This is readily explainable from the influence of temperature on the different stages. The earliest spring pupal stages lasted a month, but the later individuals to transform spent only 2 weeks as pupæ; so that the time of emergence of the spring moths was shortened by 15 days. Again, the first eggs required 20 days to hatch, and the last only 5, a shortening by another 15 days of the period during which the first brood of larvæ entered the fruit.

In 1907 the first larva was found in the orchard May 18, newly hatched, and in the act of entering the calyx. This was 6 weeks after the petals had fallen from the apple trees. Several wormy apples were found May 23, and they soon became abundant. On June 17 to 20, observations by Mr. Dudley Moulton at Bentonville, Ark., and by the writer at Siloam Springs indicated that the first brood had nearly all entered. Over 500 wormy apples were collected in orchards at the two places, but no larvæ just entering were found, the smallest larvæ having burrowed to the core.

Maturing of larvæ.—In 1908 the first cocoon was found under a band May 27, and contained a newly transformed pupa (soft and white), indicating that the larva had left the fruit not later than May 24. Two full-grown larvæ left picked fruit May 26, the fruit having been collected in the orchard that day. The band record from 18 trees (page 24) indicates that the last of the first brood of larvæ went into cocoons about July 15, or 52 days after the first larva left the fruit. This gives an increase of about a week over the time between the first and last entering larvæ of this brood.

In 1907 the first mature larvæ left picked fruit June 12. On June 17 many larvæ and some pupæ were taken from bands, the last previous examination of the bands being on June 10. In 1906 larvæ had begun to spin cocoons by June 5, as indicated by a sending of wormy fruit from Bentonville, Ark., by Mr. W. M. Scott to Mr. Moulton. Several larvæ had spun up en route.

Period in fruit.—Several of the earlier larvæ of the first brood hatched and were placed on bagged fruit May 4. Six larvæ reached maturity, leaving the fruit May 26–29, after an average life in the apple of 23.8 days, the minimum being 22 and the maximum 25 days. A greater range would probably occur in the field between larvæ in exposed fruit and those in the shaded interior of the trees.

Larval life in cocoon.—Forty-three larvæ which became full grown before July 10 showed an average interval of 7.2 days between leaving the fruit and pupation when kept in vials out of doors. The shortest interval was 3 days and the longest 19. The normal time in the orchard is probably nearer the minimum here shown, as in the glass vials many larvæ seemed to spend an unusually long time trying to build a suitable cocoon. Individual records on this stage are given in Table VIII.

FIRST-BROOD PUPÆ.

First-brood larvæ began to pupate May 27, just a week after the last stragglers of the wintering larvæ under observation had pupated. Thus first-brood pupæ appeared before the last of the spring brood had given out moths, the extent of the overlap being 12 days.

Of 42 first-brood pupæ observed, the average duration of the stage was 10.7 days, ranging from 9 to 13 days. The total period from the time the larva left the fruit until the adult issued averaged 17.8 days, with a range of from 13 to 21 days. As before suggested, larvæ not confined in vials would probably pupate sooner, thus shortening the "cocoon stage." Individual records of first-brood pupæ are shown in Table VIII.

TABLE VIII.—*Pupal periods and cocoon stages of first generation.*

Individual No.	Larva left fruit.	Larva pupated.	Moth emerged.	Length of pupal stage.	Total time in cocoon.
				Days.	*Days.*
1	May 29	June 2	June 12	10	14
2	...do.....	...do.....	...do.....	10	14
3	...do.....	...do.....	...do.....	10	14
4	May 30	June 3	...do.....	9	13
5	...do.....	...do.....	June 13	10	14
6	...do.....	June 5	June 18	13	19
7	May 31	June 4	June 15	11	15
8	June 2	June 5	June 16	11	14
9	...do.....	June 6	...do....	10	14
10	...do.....	June 7	June 18	11	16
11	June 3	June 6	June 16	10	13
12	June 4	June 9	June 21	12	17
13	June 5	June 8	June 19	11	14
14	...do.....	June 12	June 23	11	16
15	...do.....	June 21	July 3	13	28
16	June 6	June 11	June 22	11	16
17	...do.....	June 13	June 24	11	18
18	June 8	...do.....	...do.....	11	16
19	...do.....	June 16	June 26	10	18
20	June 9	...do.....	June 28	12	19
21	June 11	...do.....	June 25	9	14
22	June 15	June 19	June 30	11	15
23	June 16	June 23	July 5	12	17
24	June 21	June 24	...do.....	11	14
25	June 23	June 29	July 11	12	18
26	...do.....	July 7	July 17	10	24
27	June 24	July 2	July 12	10	18
28	...do.....	July 5	July 16	11	22
29	June 27	July 7	July 17	10	20
30	June 28	July 3	July 13	10	15
31	June 30	July 7	July 17	10	17
32	July 1	July 5	...do....	12	16
33	July 2	July 8	July 18	10	16
34	...do.....	July 11	July 20	9	18
35	...do.....	July 16	July 27	11	25
36	July 3	July 9	July 18	9	15
37	July 7	July 20	Aug. 1	12	25
38	...do.....	July 26	Aug. 7	12	31
39	July 8	July 23	Aug. 2	10	25
40	July 9	July 15	July 26	11	17
41	...do.....	July 18	July 29	11	20
42	...do.....	July 25	Aug. 4	10	26

FIRST-BROOD MOTHS.

The earliest first-brood moth emerged June 8, on which date the last belated moth of the spring brood also issued. Sixteen of the earliest moths, caged June 8–15, showed an average life of 6.2 days. Oviposition began 5 days after the first moth was caged. In 1907, when a large number of moths were caged on the same date, eggs were obtained on the third day. A record of first-brood moths confined in a cage is given in Table IX.

TABLE IX.—*Life of first-brood moths (Cage III), reared from first-brood larvæ from earliest wormy apples collected in orchard, and from earliest larvæ reared in bagged fruit.*

Moths emerged and put into cage.		Moths died.		Average life of moths.	Eggs laid (at night).	
Date.	Number.	Date.	Number.		Date.	Number.
June 8	1	June 16	1	6.2 days.	June 13	2
June 9	1	June 18	1		June 14	16
June 11	1	June 19	7		June 15	26
June 12	5	June 21	7		June 16	18
June 14	2	Escaped	5		June 17	104
June 15	11				June 18	25
		Total	16			
Total	21				Total	191

In 1907 no first-brood moths were obtained until June 25. In 1906 Mr. Moulton records the issuing of a moth on June 19 from apples sent from Bentonville, Ark.

LENGTH OF LIFE CYCLE OF FIRST GENERATION.

The interval between the emergence of the first adult of the wintering brood and the earliest first-brood moth was 69 days. Starting with a spring moth emerging after the weather became warm, the life cycle would be much shorter. A moth emerging May 5 might lay eggs May 10. Eggs laid on the latter date required 7½ days to hatch. This, together with 24 days in the fruit and 18 days in the cocoon, gives a total of about 54 days as an average time for the latter half of the first generation.

THE SECOND GENERATION.

SECOND-BROOD EGGS.

The earliest of the first brood of moths began depositing eggs on the night of June 13. In 1907 second-brood eggs were not laid in cages until July 5. All eggs of this brood required a nearly uniform period of 5 days for incubation. In Table X is given a record of the incubation of some of the earlier eggs of this brood.

TABLE X.—*Second-brood eggs—incubation periods of eggs laid in Cage III (recorded in Table IX).*

Number of eggs.	Eggs laid (at night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
26	June 15	June 18	June 20	June 21	5½
18	June 16	June 19	June 21	[a]do	5
104	June 17	do	June 22	[a]June 22	5
25	June 18	June 20		June 23	5½

[a] At night.

SECOND-BROOD LARVÆ.

Period of hatching.—According to records of oviposition, the first larvæ of the second brood would have hatched June 18. They began hatching in numbers in the cages June 21. Reared larvæ entering fruit as late as August 3 were undoubtedly of the second brood, as they pupated on reaching full growth. Some of the brood probably hatched later still, making a total period of entrance to the fruit of perhaps 55 days for such larvæ of this brood as pupated.

Maturing of larvæ.—The band record (p. 24) indicates that second-brood larvæ began to leave the fruit by July 15. The first of the reared larvæ left July 13, and were from eggs laid 4 days later than the earliest, so mature second-brood larvæ may have appeared by July 10. The band records of both 1907 (p. 23) and 1908 (p. 24) indicate that the last of the second brood left the fruit early in September.

Period in fruit.—A large number of second-brood larvæ hatching during the night of June 22 were transferred to bagged fruit June 25. Seventeen of these reached maturity after an average time in the fruit of 24.6 days, the time ranging from 21 to 31 days. The individual records are given in Table XI.

TABLE XI.—*Life of second-brood larvæ, reared in bagged fruit on trees (eggs recorded in Table X).*

Number of larvæ.	When hatched.	Date of leaving fruit.	Time in fruit.
	Night.		*Days.*
1	June 22	July 13	21
4	...do.....	July 14	22
1	...do.....	July 15	23
4	...do.....	July 16	24
1	...do.....	July 17	25
2	...do.....	July 18	26
2	...do.....	July 19	27
1	...do.....	July 20	28
1	...do.....	July 23	31

Several of the same lot of larvæ were put on picked fruit and kept in jars out of doors. Most of these spun cocoons in the fruit, and had pupated before the fact was noticed. Three of them, however, left the fruit after periods of 21 and 22 days. The fact that these larvæ had been kept in jars instead of on bagged fruit seems to have hastened development, as the average time from oviposition to emergence of adult of 11 individuals of this lot was 42.3 days, as against 49.5 days for the 17 individuals on bagged fruit. Nine second-brood larvæ hatching July 28 to August 3 were reared in picked fruit in jars, and reached maturity in from 16 to 20 days, the average being 17.7 days. Individual records of this lot are given in Table XII.

TABLE XII.—*Life of second-brood larvæ, reared in picked fruit in jars out of doors.*

Number of larvæ.	When hatched.	Date of leaving fruit.	Time in fruit.
			Days.
2	July 28	Aug. 15	18
1	...do.....	Aug. 14	17
1	July 31	Aug. 17	17
1	Aug. 2	Aug. 20	18
1	Aug. 3	Aug. 22	19
1	...do.....	Aug. 23	20
1	...do.....	Aug. 19	16
1	...do.....	...do.....	16

In 1907 the period in the fruit was determined for 33 second-brood larvæ which hatched July 10–15. All were reared in picked fruit kept in the laboratory. The shortest time was 15 days, longest 22, average 18.1 days. The 1907 rearings are tabulated in Table XIII.

TABLE XIII.—*Life of second-brood of larvæ, reared in picked fruit, in laboratory—1907*

Number of larvæ.	Date of hatching.	Date of leaving fruit.	Time in fruit.
			Days.
2	July 10	July 27	17
2	...do.....	July 29	19
1	...do.....	July 30	20
1	July 15	...do.....	15
2	...do.....	July 31	16
9	...do.....	Aug. 1	17
7	...do.....	Aug. 2	18
4	...do.....	Aug. 3	19
1	...do.....	Aug. 4	20
2	...do.....	Aug. 5	21
2	...do.....	Aug. 6	22

Larval life in cocoon.—Of 75 larvæ maturing from July 12 to September 1, the time between leaving the fruit and pupation (in vials out of doors) varied from 3 to 21 days, with an average of 11.86 days. The remarks on this stage of the first-brood larvæ would also apply here. Individual records are shown in Table XIV.

SECOND-BROOD PUPÆ.

Pupæ appeared out of doors as late as September 14. These, however, were from larvæ that left the fruit September 1 or before, and only a few larvæ leaving the fruit later than August 20 transformed. In the laboratory pupæ appeared well into November. In 1907 larvæ appearing under bands later than August 26 generally failed to pupate, so that the last pupæ in both seasons appeared early in September.

Of 78 second-brood pupæ, from larvæ maturing after July 12 and until September 1, the longest pupal stage was 17 days, shortest 8, average 10.5 days. The longest total period in cocoon was 38 days, shortest 12, average 20.4 days. This material was kept in small vials, and the period between leaving the fruit and pupation was probably abnormally long, on account of the difficulty in spinning a suitable cocoon. The individual records are given in Table XIV.

TABLE XIV.—*Pupal periods and cocoon stages of second generation.*

Individual No.	Larva left fruit.	Larva pupated.	Moth emerged.	Time as pupa.	Time in cocoon.
				Days.	*Days.*
1	July 12	July 17	July 26	9	14
2	..do.....	July 22	Aug. 2	11	21
3	July 13	July 21	July 31	10	18
4	..do.....	July 24	Aug. 2	9	20
5	July 14	July 17	July 27	10	13
6	..do.....	July 28	Aug. 6	9	23
7	..do.....	..do.....	Aug. 7	10	24
8	..do.....	July 31	Aug. 10	10	27
9	July 15	July 29	Aug. 7	9	23
10	July 16	July 25	Aug. 3	9	18
11	..do.....	..do.....	..do.....	9	18
12	..do.....	July 22	July 30	8	14
13	..do.....	July 28	Aug. 7	10	22
14	July 17	Aug. 2	Aug. 11	9	25
15	July 18	July 22	July 31	9	13
16	..do.....	July 26	Aug. 4	9	17
17	July 19	..do.....	Aug. 3	8	15
18	..do.....	..do.....	..do.....	8	15
19	..do.....	July 28	Aug. 6	9	18
20	July 20	Aug. 7	Aug. 18	11	19
21	July 21	July 28	Aug. 6	9	16
22	..do.....	July 29	Aug. 7	9	17
23	July 23	July 31	Aug. 10	10	18
24	..do.....	Aug. 4	Aug. 16	12	24
25	July 24	July 30	Aug. 8	9	15
26	..do.....	Aug. 1	Aug. 11	10	18
27	July 25	Aug. 2	..do.....	9	17
28	July 29	Aug. 11	Aug. 19	8	21
29	Aug. 1	Aug. 16	Aug. 27	11	26
30	..do.....	Aug. 11	Aug. 19	8	18
31	Aug. 2	Aug. 6	Aug. 16	10	14
32	..do.....	Aug. 11	Aug. 19	8	17
33	..do.....	Aug. 12	Aug. 22	10	20
34	Aug. 3	Aug. 11	Aug. 19	8	16
35	..do.....	Aug. 14	Aug. 25	11	22
36	..do.....	Aug. 17	Aug. 28	11	25
37	Aug. 4	Aug. 11	Aug. 22	11	18
38	..do.....	Aug. 12	Aug. 21	9	17
39	..do.....	Aug. 16	Aug. 27	11	23
40	..do.....	Aug. 25	Sept. 5	11	32
41	Aug. 5	Aug. 11	Aug. 20	9	15
42	..do.....	Aug. 13	Aug. 21	8	16
43	..do.....	..do.....	Aug. 22	9	17
44	Aug. 6	Aug. 10	Aug. 18	8	12
45	..do.....	Aug. 14	Aug. 23	9	17
46	Aug. 7	Aug. 13	..do.....	10	16
47	..do.....	Aug. 15	Aug. 25	10	18
48	..do.....	Aug. 16	Aug. 27	11	20
49	..do.....	Aug. 18	Aug. 28	10	21
50	..do.....	Aug. 21	Aug. 30	9	23
51	..do.....	..do.....	Sept. 1	11	25
52	Aug. 11	Aug. 17	Aug. 27	10	16
53	..do.....	Aug. 18	..do.....	9	16
54	..do.....	Aug. 19	Aug. 30	11	19
55	..do.....	Aug. 21	Aug. 31	10	20
56	Aug. 13	Aug. 18	Aug. 27	9	14
57	Aug. 14	Aug. 21	Aug. 31	10	17
58	Aug. 15	Aug. 31	Sept. 12	12	28
59	..do.....	Aug. 19	Aug. 28	9	13
60	..do.....	Aug. 26	Sept. 6	11	22
61	Aug. 16	Aug. 24	Sept. 3	10	18
62	..do.....	..do.....	Sept. 5	12	20
63	..do.....	Aug. 25	Sept. 6	12	21
64	Aug. 17	Aug. 20	Aug. 30	10	13
65	..do.....	Aug. 29	Sept. 8	10	22
66	..do.....	Aug. 30	Sept. 10	11	24
67	Aug. 19	Aug. 25	Sept. 6	12	18
68	..do.....	Aug. 30	Sept. 11	12	23
69	Aug. 20	Aug. 29	Sept. 10	12	21
70	..do.....	Sept. 6	Sept. 17	11	28
71	Aug. 21	Aug. 28	Sept. 10	13	20
72	Aug. 24	Sept. 14	Oct. 1	17	38
73	Aug. 25	Sept. 1	Sept. 12	11	18
74	Aug. 26	Sept. 8	Sept. 20	12	25
75	Aug. 27	Sept. 6	Sept. 16	10	20
76	Aug. 28	Sept. 1	Sept. 14	13	17
77	Aug. 30	Sept. 9	Sept. 20	11	21
78	Sept. 1	Sept. 13	Sept. 25	12	24

SECOND-BROOD MOTHS.

Moths of the second brood were obtained from reared material July 25. Moths emerged in abundance during August and in diminishing numbers throughout September. The last one to emerge out of doors appeared October 1.

The earliest moths of this brood were not obtained in sufficient numbers to get the first possible third-brood eggs. Oviposition in a cage began on August 5 by moths the first of which emerged July 30. The record of this cage is given in Table XV.

TABLE XV.—*Life of second-brood moths (Cage IV), reared from second-brood larvæ recorded in Table XI.*

Moths emerged and put into cage.		Eggs laid (at night).		Moths died.	
Date.	Number.	Date.	Number.	Date.	Number.
July 30	1	August 5	2	August 9	(female) 1
July 31	1	August 6	2	August 10	(female) 1
August 2	1	August 8	55	August 11	(female) 2
August 3	3	August 9	54	August 12	(female) 2
August 4	2			do	(male) 1
August 6	1			August 13	(male) 1
August 7	3			Lost or escaped	5
August 11	1				
Total	13				

LENGTH OF LIFE CYCLE OF SECOND GENERATION.

The interval between the emergence of the earliest first-brood moth (June 8) and the earliest of the second brood (July 25) gives a period of 47 days for the life cycle. Records of 19 individuals, the larvæ being reared in bagged fruit on trees, give an average of 49.5 days from oviposition to emergence. Adding 5 days as the interval from emergence to oviposition gives 54.5 days as the total for the generation. The minimum time thus shown was 45 and the maximum 67 days. Records of these 19 individuals are given in Table XVI.

TABLE XVI.—*Records, from oviposition to emergence of adult, of 19 individuals of the second generation reared from moths recorded in Table IX—larvæ reared in bagged fruit on trees.*

Individual No.	Egg laid (at night).	Egg hatched (at night).	Larva left fruit.	Larva pupated.	Moth emerged.	Time from oviposition to emergence of adult.
						Days.
1	June 17	June 22	July 13	July 24	Aug. 2	46
2	do	do	July 14	July 17	July 27	40
3	do	do	do	July 28	Aug. 6	50
4	do	do	do	do	Aug. 7	51
5	do	do	do	July 31	Aug. 10	54
6	do	do	July 15	July 29	Aug. 7	51
7	do	do	July 16	July 25	Aug. 3	47
8	do	do	do	do	do	47
9	do	do	do	July 22	July 30	43
10	do	do	do	July 28	Aug. 7	51
11	do	do	July 17	Aug. 2	Aug. 11	55
12	do	do	July 18	July 22	July 31	44
13	do	do	do	July 26	Aug. 4	48
14	do	do	July 19	do	Aug. 3	47
15	do	do	July 20	Aug. 7	Aug. 18	62
16	do	do	July 23	Aug. 4	Aug. 16	60
17	do	do	Transformed in fruit.		Aug. 4	48
18	do	do	do		do	48
19	do	do	do		Aug. 5	49

Eleven individuals from the same lot as the above were reared in picked fruit in jars out of doors, and show an average of 42.3 days from oviposition to emergence, which would indicate about 47 days as the length of the life cycle. The records are shown in Table XVII.

TABLE XVII.—*Records, from oviposition to emergence of adult, of 11 individuals of the second generation reared from moths recorded in Table IX—larvæ reared in picked fruit, in jars out of doors.*

Individual No.	Egg laid (at night).	Egg hatched (at night).	Larva left fruit.	Larva pupated.	Moth emerged.	Time from oviposition to emergence of adult.
						Days.
1	June 17	June 22	July 13	July 21	July 31	44
2	do	do	July 14	July 17	July 28	41
3	do	do	do	July 20	July 31	44
4	do	do	Transformed in fruit.		July 25	38
5	do	do	do		July 26	39
6	do	do	do		July 28	41
7	do	do	do		July 30	43
8	do	do	do		July 31	44
9	do	do	do		July 26	39
10	do	do	do		Aug. 2	46
11	do	do	do		do	46

In 1907 records of 30 individuals reared in picked fruit in the laboratory gave a minimum time from oviposition to adult of 34 days, maximum 68, average 39.1 days. Allowing 5 days between emergence and oviposition, the length of the life cycle would be: Minimum, 39; maximum, 73; average, 49 days. These indoor records show an average life cycle 5 days shorter than the outdoor records (on bagged fruit) of 1908. Table XVIII gives a record of the 1907 rearings.

TABLE XVIII.—*Records from oviposition to emergence of adult of 30 individuals of the second generation reared in 1907 from larvæ and pupæ of the first generation collected from bands—material kept in laboratory.*

Individual No.	Egg laid.	Egg hatched.	Larva left fruit.	Moth emerged.	Time from oviposition to emergence of adult.
					Days.
1	July 5	July 10	July 27	Aug. 15	41
2	...do	...do	...do	Aug. 12	38
3	...do	...do	July 29	...do	38
4	...do	...do	...do	...do	38
5	July 10	July 15	July 30	Aug. 15	36
6	...do	...do	July 31	Aug. 13	34
7	...do	...do	...do	Aug. 14	35
8	...do	...do	Aug. 1	...do	35
9	...do	...do	...do	...do	35
10	...do	...do	...do	...do	35
11	...do	...do	...do	...do	35
12	...do	...do	...do	...do	35
13	...do	...do	...do	Aug. 16	37
14	...do	...do	...do	...do	37
15	...do	...do	...do	Aug. 25	46
16	...do	...do	Aug. 2	Aug. 15	36
17	...do	...do	...do	...do	36
18	...do	...do	...do	...do	36
19	...do	...do	...do	Aug. 21	42
20	...do	...do	...do	Aug. 22	43
21	...do	...do	...do	Aug. 27	48
22	...do	...do	Aug. 3	Aug. 15	36
23	...do	...do	...do	...do	36
24	...do	...do	...do	Aug. 16	37
25	...do	...do	...do	...do	37
26	...do	...do	...do	Sept. 16	68
27	...do	...do	Aug. 4	Aug. 17	38
28	...do	...do	Aug. 5	Sept. 1	53
29	...do	...do	(a)	Aug. 15	36
30	...do	...do	(a)	...do	36

a Spun cocoon in fruit.

THE THIRD GENERATION.

THIRD-BROOD EGGS.

In the cages third-brood eggs were first secured August 5. The calculated time for their first appearance in the field is 10 days earlier. The last eggs observed were laid in a cage October 16 by moths emerging up to October 1.

All second-brood and third-brood eggs laid before August 28 hatched in 5 days, the usual summer incubation period. During September the egg stage was gradually lengthened toward the maximum period shown in early spring eggs. The eggs from which the third-brood larvæ were reared incubated as shown in Table XIX.

TABLE XIX.—*Incubation periods of third-brood eggs laid in Cage IV (recorded in Table XV).*

Number of eggs.	Eggs laid (at night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
55	Aug. 8	Aug. 11	Aug. 13	Aug. 14, a. m.	5
54	Aug. 9	Aug. 12	Aug. 14, a. m.	Aug. 14, night	5

Records of other eggs, mostly of the third brood, laid throughout the latter part of the season are given in Table XX.

TABLE XX.—*Incubation periods of miscellaneous second-brood and third-brood eggs.*

Number of eggs.	Eggs laid (at night).	Red ring appeared.	Black spot appeared.	When hatched.	Length of egg stage.
					Days.
94	July 30			Aug. 4, evening and night.	5
23	Aug. 12	Aug. 14, p. m.	Aug. 17, a. m.	Aug. 17, night	5
18	Aug. 13			Aug. 18, p. m.	5
96	Aug. 28	Aug. 30	Sept. 2	Sept. 3, p. m.	5½-6
50	Aug. 29	Aug. 31	Sept. 4	Sept. 5	6
46	Sept. 7	Sept. 9	Sept. 13, a. m.	Sept. 13, p. m. and night.	6
37	Sept. 11	Sept. 13	Sept. 16	Sept. 17, m.	5½
3	Sept. 17		Sept. 24, a. m.	Sept. 25, p. m. and night.	8
34	Sept. 23		Oct. 3	Oct. 5, a. m.	11¼
16	Sept. 24-27			Oct. 9-15	14-18
4	Oct. 16	Oct. 18-19	Oct. 29	Dried up	13+

THIRD-BROOD LARVÆ.

In the cages the first hatching of third-brood larvæ was on August 14. Judging from the emergence of second-brood moths July 25, third-brood larvæ probably appeared in the field during the first week of August. Owing to the early dropping of the small crop of fruit in 1908, field observations on larvæ entering fruit could not be made during September. In the cages larvæ continued to hatch in numbers up to September 20, and the last on October 15. The last lot of eggs developed as far as the black-spot stage on October 29, but failed to hatch.

As the harvesting of the apple crop in this region ordinarily begins early in September, considerable numbers of the third brood would fail to mature before fruit picking. Reared larvæ of this brood began to mature September 2, and the band record for 1907 (p. 23) also shows an increase about this time. The calculated time of maturing of the earliest third-brood larvæ in 1908 is August 20. Owing to the dropping of the fruit in 1908, the band record for this season (p. 24) does not include a normal number of the later larvæ. In 1907 larvæ spun cocoons under the bands as long as any apples were on the trees, and at harvest time many small worms were still in the fruit.

Forty-one third-brood larvæ, hatching August 14 and reared in picked fruit in jars out of doors, required from 19 to 32 days to become full grown, the average being slightly over 24 days. These records are given in Table XXI.

TABLE XXI.—*Life of third-brood larvæ, reared in picked fruit in jars out of doors, from eggs recorded in Table XIX.*

Number of larvæ.	When hatched.	Date of leaving fruit.	Time in fruit.
			Days.
2	Aug. 14, a. m.	Sept. 2	19
2	.....do........	Sept. 3	20
1	.....do........	Sept. 4	21
3	.....do........	Sept. 5	22
8	.....do........	Sept. 7	24
3	.....do........	Sept. 8	25
2	.....do........	Sept. 9	26
1	.....do........	Sept. 11	28
1	.....do........	Sept. 12	29
1	.....do........	Sept. 14	31
1	.....do........	Sept. 15	32
1	Aug. 14, night.	Sept. 3	19
2	.....do........	Sept. 4	20
2	.....do........	Sept. 5	21
1	.....do........	Sept. 6	22
3	.....do........	Sept. 7	23
2	.....do........	Sept. 8	24
1	.....do........	Sept. 11	27
1	.....do........	Sept. 12	28
2	.....do........	Sept. 14	30
1	.....do........	Sept. 15	31

Total number, 41.

All reared larvæ of the third brood were of the wintering generation.

WINTERING LARVÆ.

A few erratic larvæ maturing early in the season failed to pupate. They remained in their cocoons throughout the season, apparently in a perfectly healthy condition. The first of these left the fruit June 9 and was undoubtedly of the first brood. Two others leaving the fruit July 2 and 4 were also probably of this brood. One wintering larva left the fruit July 10, two July 19, and one August 2. All the above larvæ were from collected wormy fruit. Among 20 of the earlier second-brood larvæ reared in bagged fruit (Table XXVI), 1 wintering larva left the fruit July 19. In 1907, out of 41 second-brood larvæ reared in the laboratory (Table XXIX), 5 that did not pupate left the fruit August 1–6.

Beginning August 20, the percentage of wintering larvæ leaving the fruit suddenly arose to include the majority. In 1907 this happened about the same time. A record of the material collected in taking the band records at this period will illustrate the transition. This is shown in Tables XXII and XXIII.

Table XXII.—*Transition to wintering larvæ in 1907.*

Larvæ forming cocoons under bands.	Number pupating.	Number wintering.
July 22–29	112	1
July 29–August 5	193	1
August 5–12	144	4
August 12–19	121	36
August 19–26	50	46
August 26–September 2	8	36
September 2–9	0	52

Table XXIII.—*Transition to wintering larvæ in 1908.*

[From record made by Mr. S. W. Foster.]

Larvæ forming cocoons under bands.	Number pupating.	Number wintering.
July 13–20	15	1
July 20–27	26	0
July 27–August 3	27	1
August 3–10	63	6
August 10–17	16	6
August 17–24	11	12
August 24–31	1	5
August 31–September 7	0	11

After September 1 all larvæ appearing under bands were of the wintering brood. While some of the later second-brood larvæ may go over winter, there is evidence that most of them produce a second brood of moths instead. The species is therefore dependent largely upon the third-brood larvæ to perpetuate itself from season to season.

Conditions affecting wintering larvæ in the orchard were not observed. Around the out door apple bin at a vinegar factory where large numbers of cocoons were examined in March and April the great majority of them contained live larvæ or pupæ.

REVIEW OF REARING WORK OF THE SEASON.

An effort was made to rear through the season a continuous line of pedigreed stock from the earliest spring moths, with the principal object of ascertaining the maximum number of generations. With the exception of one unimportant break early in the season, this program was successfully carried out.

The start was made from a number of eggs collected in the field and hatching May 4, several days before the hatching of the first eggs laid in cages. The larvæ were reared in bagged fruit on trees, and developed into first-brood adults as shown in Table XXIV.

TABLE XXIV.—*Records, from hatching of egg to emergence of adult, of 4 individuals of the first generation. (Reared from first eggs found in orchard.)*

Egg hatched.	Larva left fruit.	Larva pupated.	Moth emerged.
May 4....	May 26	May 30	June 8
Do.....	May 27	May 31	June 9
Do.....	May 28	June 1	June 13
Do.....	May 29	June 2	June 12

Not enough adults were obtained in this rearing to insure oviposition for the second generation, so other adults reared from the earliest wormy apples from the orchard were put into the cage. This is the only break in the line of descent, where outside material had to be added. However, there can be no doubt that all these moths were of the first brood. In Table XXV is given the record of oviposition of these moths.

TABLE XXV.—*Life of moths of first brood, reared from first-brood larvæ from earliest wormy apples collected in orchard, and from earliest larvæ reared in bagged fruit.*

Moths emerged and put into cage.		Eggs laid (at night).		Moths died.	
Date.	Number.	Date.	Number.	Date.	Number.
June 8	1	June 13	2	June 16	1
June 9	1	June 14	16	June 18	1
June 11	1	June 15	26	June 19	7
June 12	5	June 16	18	June 21	7
June 14	2	June 17	104	Escaped	5
June 15	11	June 18	25		

While not the earliest, the eggs laid on the night of June 17 were selected, on account of their numbers, to start the second generation. Some of the larvæ hatching from these eggs were put on bagged fruit, and others were reared in picked fruit kept out of doors in jars. Those on bagged fruit developed as shown in Table XXVI.

TABLE XXVI.—*Records, from oviposition to emergence of adult, of 20 individuals of the second generation, reared from moths recorded in Table XXV—larvæ reared in bagged fruit on trees.*

Individual No.	Egg hatched (at night).	Larva transferred to bagged fruit.	Larva left fruit.	Larva pupated.	Moth emerged.
1	June 22	June 25	July 13	July 24	Aug. 2
2	...do.....	...do.....	July 14	July 17	July 27
3	...do.....	...do.....	...do.....	July 28	Aug. 6
4	...do.....	...do.....	...do.....	...do.....	Aug. 7
5	...do.....	...do.....	...do.....	July 31	Aug. 10
6	...do.....	...do.....	July 15	July 29	Aug. 7
7	...do.....	...do.....	July 16	July 25	Aug. 3
8	...do.....	...do.....	...do.....	...do.....	Do.
9	...do.....	...do.....	...do.....	July 22	July 30
10	...do.....	...do.....	...do.....	July 28	Aug. 7
11	...do.....	...do.....	July 17	Aug. 2	Aug. 11
12	...do.....	...do.....	July 18	July 22	July 31
13	...do.....	...do.....	...do.....	July 26	Aug. 4
14	...do.....	...do.....	July 19	...do.....	Aug. 3
15	...do..	...do.....	July 20	Aug. 7	Aug. 18
16	...do.....	...do.....	July 23	Aug. 4	Aug. 16
17	...do.....	...do.....	Transformed in fruit.		Aug. 4
18	...do.....	...do.....	...do...		Do.
19	...do.....	...do.....	...do...		Aug. 5
20	...do.....	...do.....	July 19	Wintering.	

To secure third-brood eggs, only moths that developed from the second-brood larvæ on bagged fruit were used. These emerged and oviposited as recorded in Table XXVII.

TABLE XXVII.—*Life of moths of second brood, reared from material recorded in Table XXVI.*

Moths emerged and put into cage.		Eggs laid (at night).		Moths died.	
Date.	Number.	Date.	Number.	Date.	Number.
July 30	1	August 5	2	August 9	(female) 1
July 31	1	August 6	2	August 10	(female) 1
August 2	1	August 8	55	August 11	(female) 2
August 3	3	August 9	54	August 12	(female) 2
August 4	2			Do	(male) 1
August 6	1			August 13	(male) 1
August 7	3				
August 11	1				
Total	13			Lost or escaped	5

The eggs laid August 8 and 9 developed a third brood of larvæ as shown in Table XXVIII.

TABLE XXVIII.—*Life of larvæ of third brood, reared from eggs recorded in Table XXVII.*

Eggs laid (at night).	Eggs hatched.	Number of larvæ.	Larvæ left fruit.
Aug. 8	Aug. 14, a. m.	2	Sept. 2
Do	do	2	Sept. 3
Do	do	1	Sept. 4
Do	do	3	Sept. 5
Do	do	8	Sept. 7
Do	do	3	Sept. 8
Do	do	2	Sept. 9
Do	do	1	Sept. 11
Do	do	1	Sept. 12
Do	do	1	Sept. 14
Do	do	1	Sept. 15
Aug. 9	Aug. 14, night.	1	Sept. 3
Do	do	2	Sept. 4
Do	do	2	Sept. 5
Do	do	1	Sept. 6
Do	do	3	Sept. 7
Do	do	2	Sept. 8
Do	do	1	Sept. 11
Do	do	1	Sept. 12
Do	do	2	Sept. 14
Do	do	1	Sept. 15

The above larvæ were reared out of doors in picked fruit. All of them were of the wintering generation.

THIRD GENERATION IN 1907.

In 1907 all the rearing was done in the laboratory. The first larvæ and pupæ collected in taking the band record (first generation) were used to begin rearing for a third generation. From this material first-brood moths began to emerge June 25. Second-brood eggs were laid by them in large numbers July 5 to 20, from which 41 second-brood larvæ developed as shown in Table XXIX.

TABLE XXIX.—*Records of 41 individuals of the second generation, reared in the laboratory in 1907, from band-collected larvæ and pupæ of the first generation.*

Number of individuals.	Eggs hatched.	Larvæ left fruit.	Moths emerged.	Number of individuals.	Eggs hatched.	Larvæ left fruit.	Moths emerged.
1	July 10	July 27	Aug. 15.	2	July 15	Aug. 3	Aug. 15.
1	...do.....	...do.....	Aug. 12.	1	...do.....	...do.....	Aug. 16.
2	...do.....	July 29	Do.	1	...do.....	...do.....	Do.
1	...do.....	July 30	Pupa died.	1	...do.....	...do.....	Sept. 16.
1	July 15	...do.....	Aug. 15.	1	...do.....	Aug. 4	Aug. 17.
1	...do.....	July 31	Aug. 13.	1	....	...do.....	Aug. 16.
1	...do.....	...do.....	Aug. 14.	1	....	...do.....	Wintering.
5	...do.....	Aug. 1	Do.	1	....	...do.....	Aug. 15.
1	...do.....	...do.....	Aug. 16.	1	July 15	Aug. 5	Sept. 1.
1	...do.....	...do.....	Do.	1	...do.....	...do.....	Wintering.
1	...do.....	...do.....	Aug. 25.	1	...do.....	Aug. 6	Do.
3	...do.....	Aug. 2	Aug. 15.	1	...do.....	...do.....	Do.
1	...do.....	...do.....	Aug. 21.	1	....	Aug. 7	Aug. 18.
1	...do.....	...do.....	Aug. 22.	1	....	...do.....	Aug. 20.
1	...do.....	Aug. 1	Wintering.	1	....	Aug. 9	Aug. 25.
1	...do.....	Aug. 2	Aug. 27.	2	July 15	(a)	Aug. 15.

a Pupated in fruit.

As indicated in the table, 5 of these larvæ lived over winter, while the others developed to second-brood moths. No attempt was made to secure third-brood eggs from these moths, but from the time of their emergence we should expect third-brood larvæ to begin hatching about August 20.

MISCELLANEOUS OBSERVATIONS.

BAND RECORDS.

A band record is an important aid in tracing the seasonal history of the codling moth. The band record for 1907 is given in Table XXX and is shown graphically in figure 2.

TABLE XXX.—*Band record of 1907, made from 25 trees in an unsprayed orchard.*

Date.	Number of larvæ and pupæ taken from bands.	Date.	Number of larvæ and pupæ taken from bands.
June 3	0	August 5	212
June 10	0	August 12	168
June 17	28	August 19	170
June 24	48	August 26	98
July 1	25	September 2	46
July 8	47	September 9	52
July 15	56	September 16	67
July 22	75	October 7	156
July 29	131		

The gap between the first-brood and the second-brood larvæ, indicated in the 1907 band record at July 1, should have come a week or more later. The week ending July 1 was cool and very rainy, the bands being continuously wet. This must have delayed many larvæ in leaving the fruit, and prevented others from selecting the bands as a place for spinning their cocoons.

The third brood shown in the 1907 band record (beginning September 2) is probably normal in bulk, though the curve should perhaps rise more abruptly and stop earlier at the date of harvesting the apples. There were taken October 7 from the bands 156 larvæ, an average of 52 per week since the last previous examination; meanwhile the fruit had been gathered, but the exact date could not be ascertained. Picking the fruit would of course put an end to the band record.

It will be noticed in the curve (fig. 2) that the second brood is many times larger than the first. But the third brood, instead of showing a further increase, is scarcely larger than the first. This is not to be taken as evidence of only a partial brood, but is due to the fact that the fruit was harvested before the bulk of the third brood had matured.

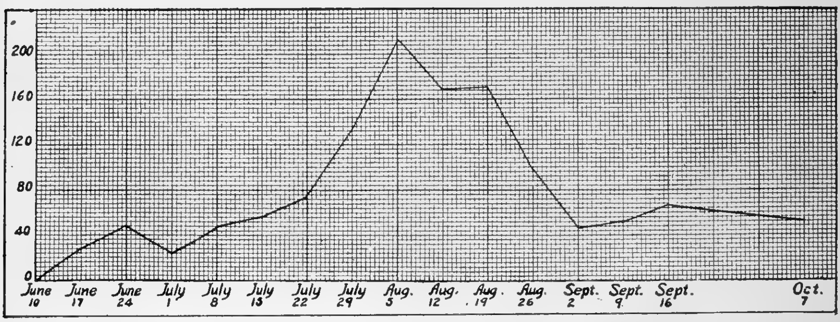

FIG. 2.—Curve showing record of larvæ and pupæ of the codling moth taken from bands in 1907.

The 1908 band record (Table XXXI and fig. 3) was influenced by the very smal' size of the apple crop in that year.

TABLE XXXI.—*Band record of 1908, made from 18 trees in an orchard sprayed once after the calices had closed.*

[Record by Mr. S. W. Foster.]

Date.	Number of larvæ and pupæ taken from bands.	Date.	Number of larvæ and pupæ taken from bands.
June 6–15	62	August 3	28
June 22	45	August 10	69
June 29	67	August 17	30
July 6	66	August 24	23
July 13	31	August 31	6
July 20	16	September 7	11
July 27	26	September 14	2

The trees from which this record was made had lost all their fruit by September 7.

In the 1908 band record the smaller size of the second brood as compared with the first is due to the fact that the very small crop of apples became so infested that they fell from the trees before a large number of the later larvæ had matured. For the same reason the

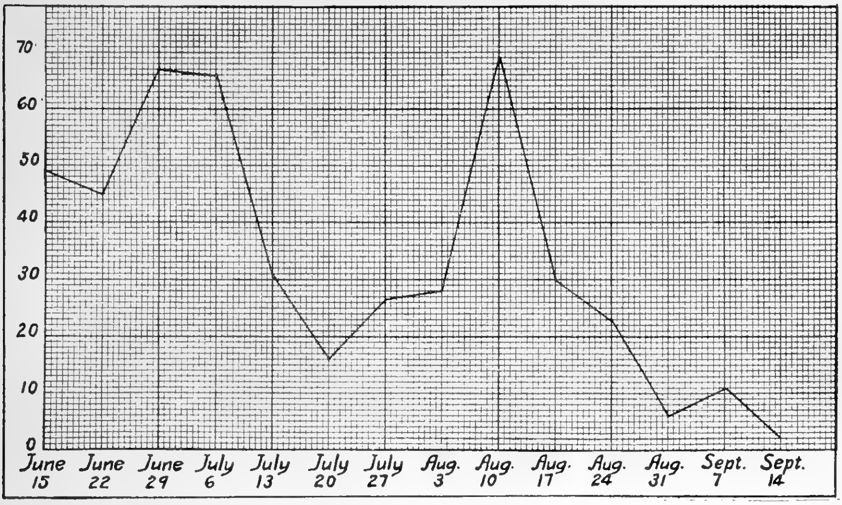

FIG. 3.—Curve showing band record of 1908.

third brood is not represented. The record was not begun in time to include the earliest larvæ, which had begun to leave the fruit May 24.

A band record made in 1908 by Mr. F. W. Faurot (figs. 4 and 5) at Anderson, Mo., 40 miles north of Siloam Springs, is interesting

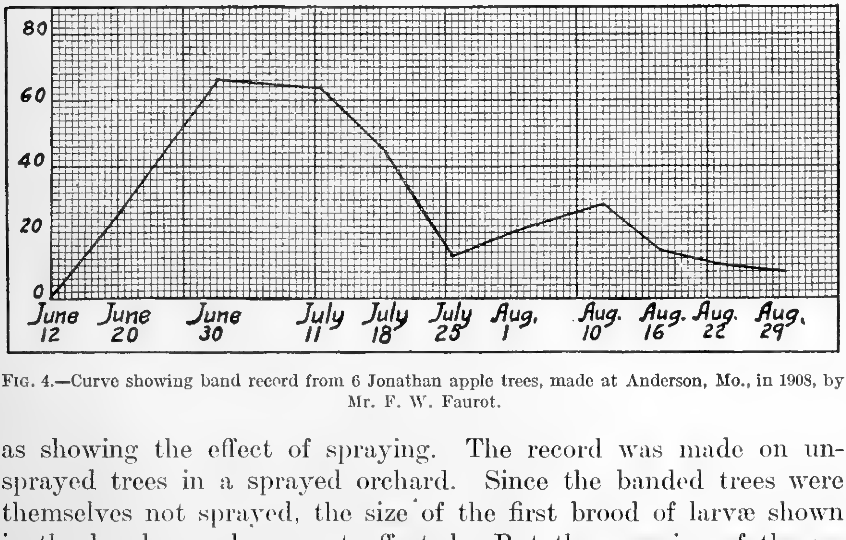

FIG. 4.—Curve showing band record from 6 Jonathan apple trees, made at Anderson, Mo., in 1908, by Mr. F. W. Faurot.

as showing the effect of spraying. The record was made on unsprayed trees in a sprayed orchard. Since the banded trees were themselves not sprayed, the size of the first brood of larvæ shown in the band record was not affected. But the spraying of the remainder of the orchard, and the killing of all larvæ and pupæ taken from the bands, caused a marked reduction, instead of the normal increase, in the size of the second brood.

The part of this record from 6 Jonathan trees, from which the fruit was picked the last of August, thus shutting out the third brood, is separated from the remainder. Figure 4 shows the record from these trees, and figure 5 the remainder of the record, taken from 5 Gano and 9 Lansingburg trees, the latter a very late variety.

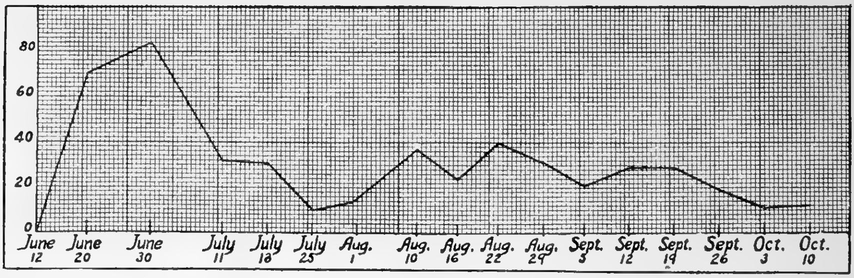

FIG. 5.—Curve showing band record from 14 Gano and Lansingburg apple trees, made at Anderson, Mo., in 1908, by Mr. F. W. Faurot.

EMERGENCE OF MOTHS.

All larvæ and pupæ collected in taking the band records at Siloam Springs were kept in muslin-covered jars, in order to record the issuing of adults. The material of 1907 was kept in the laboratory, and that of 1908 out of doors. Weekly summaries of the emergence of the moths are given in Tables XXXII and XXXIII and in figures 6 and 7.

TABLE XXXII.—*Laboratory record of emergence of adults from material collected in taking band record in 1907.*

Date.	Number of moths emerging.	Date.	Number of moths emerging.
June 28–July 4	23	August 15–22	113
July 4–11	16	August 22–29	111
July 11–18	29	August 29–September 5	58
July 18–25	29	September 5–12	13
July 25–August 1	39	September 12–19	2
August 1–8	48	September 20	1
August 8–15	176	October 4	1

TABLE XXXIII.—*Outdoor record of emergence of adults from material collected in taking band record in 1908.*

[Records by Mr. S. W. Foster.]

Date.	Number of moths emerging.	Date.	Number of moths emerging.
June 22–29	18	August 2–8	2
June 29–July 6	43	August 8–15	22
July 6–13	40	August 15–22	23
July 13–20	38	August 22–29	31
July 20–27	40	August 29–September 5	6
July 27–August 2	38	September 5–12	2

It will be noticed that the curves illustrating the emergence records follow closely the contour of the corresponding band-record curves, as far as the first and the second broods are concerned. The third brood is, of course, not represented in the emergence records. A record of the emergence of the third brood of 1907 (spring brood of 1908) is given on page 5, figure 1.

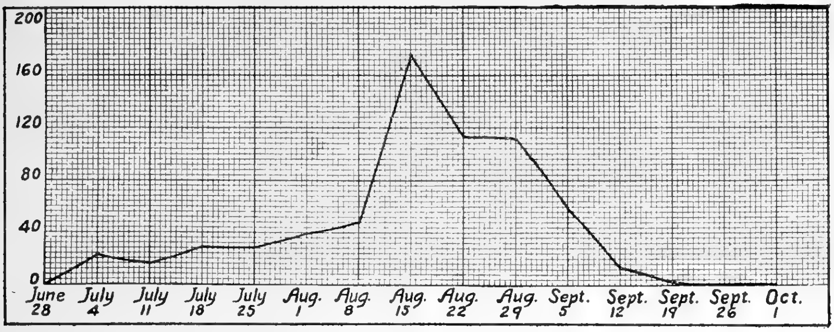

FIG. 6.—Curve showing emergence of adults from material collected in taking band record in 1907.

The ratio in size of the second brood of adults to the second brood of larvæ is practically the same as between the first-brood adults and the first-brood larvæ, shown in the emergence and the band records, respectively. This shows that as large a proportion of the second-brood as of the first-brood larvæ transform to adults; which is evidence that there is nearly a full third brood.

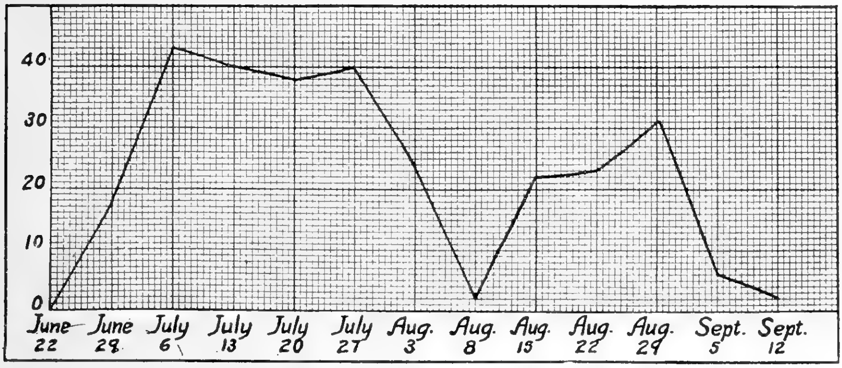

FIG. 7.—Curve showing emergence of adults from material collected in taking band record in 1908.

LARVÆ ON FOLIAGE.

Two larvæ just hatched were inclosed in paper bags on water sprouts May 4. The twigs were not examined again until May 29. In each case there was evidence of work by the larvæ. On one twig the feeding was confined to a leaf, but on the other four the young larvæ had bored down the tender end of the sprout from half an inch to 2 inches. No remains of the larvæ could be found. They had apparently bored down the twigs until they encountered wood too hard for them to chew, when they left the burrows and were lost.

In the laboratory four larvæ just hatched were put on foliage May 7. The ends of the twigs were stuck into a bottle of water, cotton was stuffed around the neck of the bottle, and the whole put under a bell jar. Two larvæ were working May 12. On May 23 one larva was still feeding. It had begun work on a leaf, then it bored into the midrib and through the petiole into the end of the twig. The larva was transferred to a fresh twig, and when again examined, May 29, had burrowed for a distance of 1¼ inches. Then it had left the burrow, and forcing its way through the cotton at the neck of the bottle had drowned itself therein. It had reached a length of 9.5 millimeters and appeared to have passed the fifth molt.

LARVÆ IN PEACHES.

Two peaches containing codling-moth larvæ were collected in the orchard, on trees adjoining an apple orchard. Both peaches ripened several days before the larvæ left them. One larva issued July 28 from a peach collected July 10. The adult emerged August 10. Another peach collected July 29 gave out a larva on August 2, from which the adult emerged August 16.

NUMEROUS LARVÆ IN ONE APPLE.

Throughout the season, and also in 1907, it was noticed that when large numbers of young larvæ were allowed to enter a single apple at the same time, only a few survived. If larvæ being reared from eggs laid in cages were not transferred to separate fruits within three to five days after hatching, or before their burrows reached the core, only a small proportion of the number entering could be accounted for.

Some third-brood larvæ entering fruit in cages were left undisturbed, the apples being kept in jars out of doors. The results, given in Table XXXIV, show that more than one larva is not likely to reach maturity in a single fruit at the same time.

TABLE XXXIV.—*Record of maturing larvæ from 4 apples, each infested at the same time by numerous larvæ.*

Eggs hatched.	Number of larvæ entering apple.	Larvæ formed cocoons.		Number of larvæ maturing.
		Date.	Number.	
Aug. 14..	18	Sept 5	1	1
Do.....	11	Sept. 5; spun cocoon in fruit.	1 1	2
Sept. 14..	18	Oct. 20	1	1
Do.....	8	...do....	1	1

NUMBER OF MOLTS.

A large number of larvæ were reared separately in pieces of apple in vials. Immediately after hatching they were transferred to the vials, and were examined daily, or at least every second day. At each examination they were changed to fresh food.

Either the frequent disturbance or the lack of apple seeds in their diet caused the larvæ to develop very slowly and to become dwarfed. The mature larvæ were very much undersized, and some of the moths that developed from them were scarcely larger than adults of the lesser apple worm (*Enarmonia prunivora* Walsh).

The normal number of molts is apparently 6 (7 instars), though 3 of the 12 larvæ that reached maturity molted 7 times (8 instars). The period of development was so much lengthened and the larvæ were so dwarfed that no conclusions can be given as to the normal length of the various instars or the size of the larva in each.

In Table XXXV are given the individual records (omitting measurements) of the 12 larvæ that reached maturity.

TABLE XXXV.—*Number of molts of the codling moth—laboratory observations on larvæ reared in pieces of apple in vials.*

Individual No.	When hatched.	Molts.							Larva formed cocoon.
		I.	II.	III.	IV.	V.	VI.	VII.	
1	Aug. 17	Aug. 21	....	Sept. 2	Sept. 9	Sept. 16	Sept. 26	....	Oct. 13
2	...do	....	Aug. 28	Sept. 1	Sept. 7	Sept. 14	Sept. 21	....	Oct. 6
3	...do	Aug. 23	Aug. 29	Sept. 4	Sept. 10	Sept. 16	Sept. 27	....	Oct. 15
4	...do	...do	....	Sept. 2	Sept. 8	Sept. 19	....	....	Oct. 7
5	...do	Aug. 24	Aug. 29	Sept. 4	Sept. 11	Sept. 17	Sept. 27	....	Oct. 16
6	...do	Aug. 23	Aug. 28	Sept. 1	Sept. 8	...do	Sept. 30	Oct. 19	Oct. 26
7	Aug. 18	Aug. 24	Aug. 29	Sept. 3	Sept. 10	Sept. 19	Oct. 3	....	Oct. 21
8	Sept. 3	Sept. 9	Sept. 14	Sept. 21	Sept. 29	Oct. 13	Oct. 30	Nov. 20	Dec. 4
9	...do	...do	...do	....	Oct. 2	Oct. 11	Oct. 23	Nov. 9	Dec. 2
10	...do	Sept. 8	Sept. 15	....	Sept. 29	Oct. 13	Oct. 25	....	Nov. 20
11	...do	Sept. 9	...do	....	Oct. 2	Oct. 15	Oct. 28	....	Nov. 27
12	...do	Sept. 8	Sept. 13	Sept. 20	Sept. 28	...do	Oct. 25	....	Nov. 17

NATURAL ENEMIES.

On May 6, while bagging fruit and collecting codling-moth eggs, about a dozen specimens of a red mite (determined by Mr. N. Banks as *Trombidium* sp.) were observed crawling about the twigs and leaves. By accident one of them got into the box of collected codling-moth eggs on leaves. On examining the eggs in the laboratory later, the mite was found in the act of eating one of them. The egg upon which it was operating was in the black-spot stage. When the mite had finished, the egg had the appearance of having hatched, except that the black head and cervical shield of the embryo remained visible underneath the egg shell. The mite was then allowed to attack a larva that was just issuing from the egg, having crawled nearly all the way out. When examined three hours later, nothing was left of the larva but the head and shriveled skin. This mite was later found to be fairly common on other trees as well as apple.

Two species of ants, *Solenopsis validiusculus* Emery and *Cremastogaster bicolor* Buckley as determined by Mr. Theo. Pergande, were frequently found attacking live larvæ under bands.

An ichneumon, determined by Mr. J. C. Crawford as the commonly recorded parasite of the codling moth, *Pimpla annulipes* Brullé, was frequently reared from band-collected material. From one lot of larvæ taken from the bands, Mr. S. W. Foster reared 11 specimens of an undetermined chalcidid, possibly a secondary parasite.

Two specimens of a small tachina fly, *Tachinophyto* sp.? (determined by Mr. C. H. T. Townsend), were reared in 1907. One individual issued from a larva which was brought into the laboratory while still in the apple, though nearly full grown.

PERCENTAGE OF FRUIT INFESTED.

In 1908 the apple crop was so small that the growers did not consider it worth protecting by spraying. On account of the small crop and the lack of preventive measures, practically every apple was wormy and the fruit fell from the trees before a large number of the later larvæ had a chance to enter. In 1907, counts from 8 unsprayed trees (4 Ben Davis and 4 Winesap) showed a percentage of wormy fruit varying from 48.1 to 64.1, the average on the Winesaps being 50.7 and on the Ben Davis 60.4. A total of 20,890 apples were examined from the 8 trees, including all windfalls throughout the season. Apples infested with codling moth, *Enarmonia prunivora* Walsh, and *Epinotia pyricolana* Murtfeldt were classed together as "wormy" fruit. Curculio injury was disregarded.

So small a percentage of infestation seems rather remarkable in a locality such as this, where at least a majority of the insects pass through three generations, while in other fruit-growing districts with a shorter season an unprotected apple crop is completely destroyed by the codling moth. Perhaps the third generation may be a disadvantage in the increase of the insect, as a considerable proportion of this brood, being yet in the fruit when the crop is harvested, is removed from the orchard (see 1907 band record, p. 23). And it must be that many of the later larvæ to hatch would even fail to find any fruit to enter, as the apple harvest usually begins early in September.

CONCLUSIONS.

Three generations of larvæ of the codling moth occur in the Ozarks of northern Arkansas, and most of the members of the second generation develop into adults.

The date at which larvæ begin to enter the fruit, relative to the blossoming of apple trees, is susceptible to great variation on account of weather conditions. In the two seasons under observation the interval was 6 and 3 weeks, respectively, between the falling of apple blossoms and the hatching of the first larvæ.

There is a sufficient interval between the first brood and the second brood of larvæ to be noticeable in the field; so that members of the two broods, though present together, may be distinguished by their size in most cases.

The third brood of larvæ constitutes the greater part of the wintering brood. Since the principal varieties of apples are harvested in this region while considerable numbers of the third brood of larvæ are yet immature, the number of larvæ wintering in the orchard is materially reduced. A smaller percentage of fruit is infested by the codling moth in this locality than in many places where only two generations are developed.

A summary of the seasonal history of the insect for the year 1908, as detailed in the preceding pages, is shown diagrammatically in figure 8.

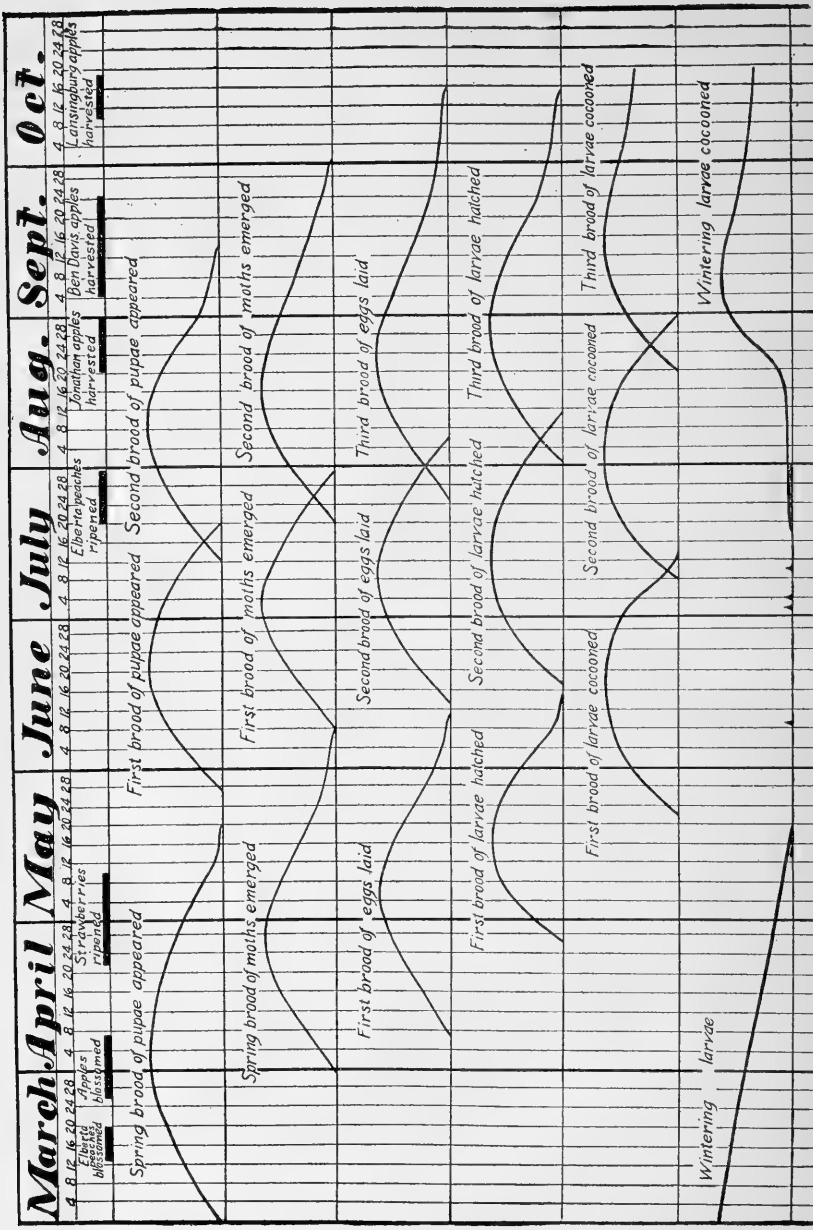

FIG. 8.—Diagram illustrating the seasonal history of the codling moth as observed in 1908 at Siloam Springs, Ark.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part II.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CIGAR CASE-BEARER.

BY

A. G. HAMMAR,

Engaged in Deciduous Fruit Insect Investigations.

ISSUED JUNE 30, 1909.

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1909.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

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THE CIGAR CASE-BEARER.

(*Coleophora fletcherella* Fernald.)

By A. G. Hammar,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the past several years the cigar case-bearer (*Coleophora fletcherella* Fernald) has occasionally come to notice on account of the injuries inflicted by it on the foliage and fruit of apple and pear trees, especially the former.

Although apparently common in different sections of the country its presence is readily overlooked, owing to its small size and the concealed life of the larva. When occurring in large numbers it first attracts attention during May and June, at which time the insect is most active and feeding freely upon the foliage. The larva itself is in a small cylindrical or cigar-shaped case, which is composed of a portion of the skin of the leaf.

In its feeding habits the larva is, to a certain extent, a miner. It always carries its case for protection, however, protruding from it when feeding. Upon close observation of the feeding marks on the foliage it will be found that they consist of a more or less round undermined area, from which the parenchyma has been removed, with a minute circular hole through the skin of the leaf, through which the larva made its entrance. By these markings on the leaves and by the cigar-shaped cases (fig. 9) of the larva the insect is readily distinguished from other related orchard pests. The cigar case-bearer has occasionally proved itself capable of destroying the foliage of entire orchards. Crop failures and various deformities of the fruit have also been ascribed to this insect.

HISTORY.

The attention of entomologists was first called to the destructiveness of the cigar case-bearer in 1888, when Mr. P. Barry, of Rochester, N. Y., found the larvæ feeding upon the young fruit of pears. Specimens of the insect were sent to Dr. J. A. Lintner, as recorded in his Fifth Report, page 324 (1889). Based upon the information and studies of the living material received from Mr. Barry, Doctor Lintner later gave an account of the insect before the Western New York Horticultural Society in 1890, under the title, "A New Pear Insect, *Coleophora* sp.," with a brief description of the insect and its life history and recommending an arsenical spray for its control in case it should appear in injurious numbers. Later the same account was reprinted in Popular Gardening for 1890, and in 1891 it was included in Doctor Lintner's seventh report as state entomologist of New York.

About the same time as noted in the Rochester occurrence, the insect attracted attention in orchards in Canada. Dr. James Fletcher in 1889 received some larvæ from Charlestown, Prince Edward Island, which were found feeding on plum trees. Soon after they were also found depredating upon apple and pear. In 1891 Dr. D. Young, of Adolphustown, Ontario, informed Doctor Fletcher of their abundance in orchards of that locality, and during the same year further reports of the insect came in from Port Williams, Nova Scotia. At Adolphustown Doctor Young carried out extensive spraying experiments with kerosene emulsion and Paris green. A full account of these and other experiments will be found in Fletcher's various publications from 1891 to 1894. Prof. C. H. Fernald, in 1892, described the new insect, naming it *fletcherella* in honor of Doctor Fletcher, who had submitted specimens for determination. He also mentions having received specimens from Lintner, who, in his ninth report (1893), showed that the case-bearer referred to in his earlier reports was this same species. Further notes on the insect in Canada were given by Fletcher in the Report of the Entomological Society of Ontario for 1894.

Prof. L. H. Bailey in 1895 reported that the failure of the apple crop in Wayne and Monroe counties, N. Y., was to a great extent due to the damages caused by the cigar case-bearer. The same year Professor Slingerland published a valuable account of the insect, giving a detailed description of it and of its life history, with excellent photographic illustrations and a full bibliography.

Prof. T. D. A. Cockerell in 1896 reported its introduction at Santa Fe, N. Mex., the young larvæ evidently having been brought in on infested nursery stock from the State of New York.

A hymenopterous parasite, *Microdus laticinctus* Ashm., was obtained by Fletcher from cases from Port Hope, Ontario.[a]

In 1898 Faville reported the occurrence of the insect at Manhattan, Kans., where for several years it had caused much injury.

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[a] Twenty-seventh Ann. Rep. Ent. Soc. Ont., 1897, p. 67.

A brief account of the life history of the insect is given by Dr. E. P. Felt in the Country Gentleman for November, 1901, and it is referred to by the same writer in his Illustrated Descriptive Catalogue of Some of the More Injurious and Beneficial Insects of New York State.[a]

Prof. S. A. Forbes in 1900 gave a brief note on a similar insect feeding on sugar beet. At the time this was supposed to be *C. fletcherella* Fernald, having very similar habits and appearance. Mr. August Busck, of this Bureau, however, has recently examined specimens sent by Professor Forbes and finds that they belong to a different species.

In 1902 it was included in Banks's Principal Insects Liable to be Distributed on Nursery Stock.[b] It is here recorded feeding upon pear and quince.

Specimens were received by Doctor Fletcher from Victoria, British Columbia, in 1905, and were sent by him to this Bureau for determination. The moths, which were examined by Mr. Busck, were found to be slightly smaller than those from New York or eastern Canada. Recently Mr. Busck has been kind enough to reexamine the specimens, and from a comparison of later collected material in the United States National Museum collection considers those from Victoria to be identical. The larvæ of the moths mentioned above were found feeding on hawthorn. The difference in size is probably due to local conditions and to the different food plant.

In a letter dated February 16, 1909, to this Bureau, Prof. R. H. Pettit, of the Michigan Agricultural College, states that he received specimens of the cigar case-bearer from Port Hope, Mich., where in 1908 it was reported as being quite a serious pest.

During the summer of 1908 the writer had the opportunity of studying the cigar case-bearer at North East, Pa. A small orchard of 40 or 50 trees belonging to Mr. A. L. Short was, in the early part of June, so badly infested by the insect that literally every leaf had been devoured.

Mr. R. W. Braucher, of this Bureau, during the summer of 1908 observed the insect at Douglas, Mich., where it was found more or less frequently in different orchards.

DISTRIBUTION.

The cigar case-bearer is evidently a native insect, feeding originally on crab apples and hawthorn. Although at present recorded only from scattered sections of the country, it is not improbable that it has a rather general distribution. In Canada, Fletcher reports it

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[a] Bull. 39, N. Y. State Mus., 1900.

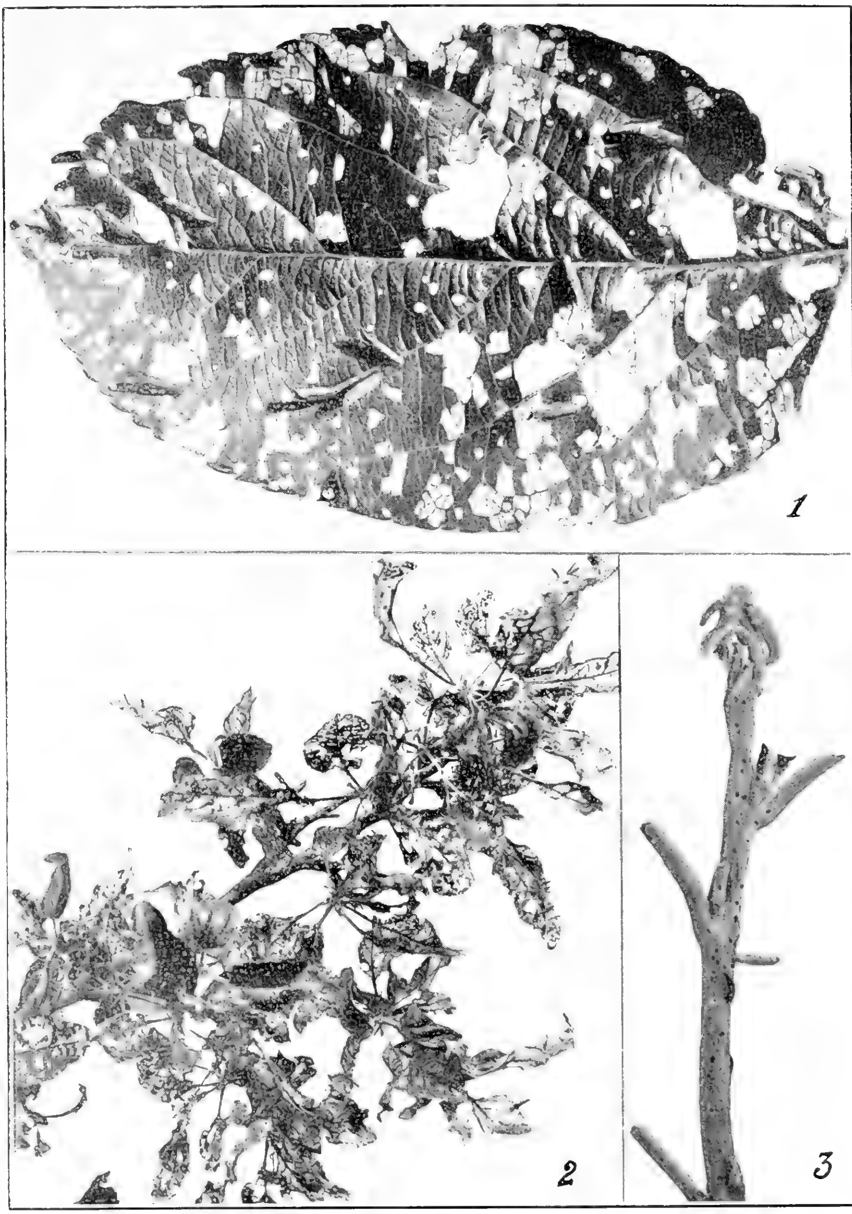
[b] Bull. 34, n. s., Div. Ent., U. S. Dept. Agr., p. 38.

from Ontario, Quebec, Nova Scotia, Prince Edward Island, and British Columbia. In the State of New York it has been recorded by Lintner, Slingerland, and others; at Manhattan, Kans., by Faville; at Santa Fe, N. Mex., by Cockerell; at North East, Pa., by the writer; at Port Hope, Mich., by Pettit, and at Douglas, Mich., by Braucher.

FOOD PLANTS AND INJURY.

The insect has a rather limited list of food plants. Originally it probably fed on native crab apples and certain species of Cratægus. With the extensive planting of orchards, it has found in apple and pear favorite food plants, and it is largely to these two fruits that its depredations have been confined. It has also been recorded feeding upon quince and plums, and will undoubtedly be found on other trees allied to them.

Like many other injurious insects, the work of the cigar case-bearer, when the species is present in destructive numbers, comes suddenly into evidence. The caterpillars infest mainly the leaves, but in the spring they may also be found on the buds and the young fruits. Injury at this time of the season is naturally quite important as affecting both the vigor of the trees and the development of the fruit. As shown in Plate I, figures 1 and 2, the foliage, under conditions of serious infestation, becomes practically skeletonized. In the orchard at North East, Pa., which came under the writer's observation in 1908, the foliage was completely devoured and withered by the early part of June, and from a distance appeared brown and dead, as if swept by fire. Neighboring fruit growers believed this to be due to the burning effect of an arsenical spray, but as a matter of fact the orchard had, to the knowledge of the present owners, never been sprayed. When inspected, June 3, the larvæ, in their cigar-shaped cases, were found in such great numbers that not only had the foliage been completely devoured, but the tender growths of the branches had been very generally attacked. (Pl. I, fig. 3.) It was probably owing to lack of food that they were dropping down from the branches, suspended by a silken thread, in search of new feeding places. The owner, Mr. A. L. Short, and his team at the time of plowing the orchard were completely covered with the larvæ and presented a very strange sight. In looking through the spaces between the rows of trees one was impressed with the abundance of the larvæ, for their cases in countless numbers, suspended by silken threads and waving back and forth in the breeze, almost resembled a drapery. As the larvæ ceased feeding by about the middle of June, the trees put out a new growth of leaves, and later in the season the condition of the orchard was favorable to its recuperation from the attack.



THE CIGAR CASE-BEARER (COLEOPHORA FLETCHERELLA).

Fig. 1.—Apple leaf with larvæ at work (enlarged). Fig. 2.—Infested apple twig, two weeks after larvæ ceased feeding (reduced). Fig. 3.—Young branches with puncturelike feeding marks of the larvæ (natural size). (Original.)

DESCRIPTION.

THE EGG.

The minute egg (fig. 10, *d*), which is hardly visible to the naked eye, is pale yellow, and over the surface is closely marked with elevated ridges. On the average, it measures 0.31 by 0.25 mm. and is almost round in outline.

THE LARVA AND ITS CASES.

When newly hatched the larva is pale yellow, with the head and thoracic plates dark brown or nearly black. The full-grown larva (fig. 10, *c*) averages 5 mm. to 5.3 mm. in length and 1.16 mm. in greatest width. Its head is 0.5 mm. wide and is dark and strongly chitinized, with the ventral surface lighter than the rest. The body is reddish orange, with dark plates as follows: The cervical plate on the prothorax, subdivided by a white interspace; two smaller plates on the dorsum of the mesothorax; a pair of lateral plates on each thoracic segment; a large anal plate on the terminal segment; a small plate on the side of each anal leg. The crochets on the fourth pair of abdominal legs are absent, and on the first three pairs are rudimentary or wanting, varying from none to 4, in one or two rows. The anal legs have from 10 to 13 well-developed crochets placed in a single row. The spiracles are round and feebly indicated. The thoracic legs are large, dark brown, strongly chitinized, and with a chitinous plate behind the basal portion of each leg. The setæ on the head, thoracic legs, and terminal portion of the body are distinct; on the abdominal segments they are rather indistinct. The abdominal segments are distinctly divided into two annulets, and the dorsal surface of each annulet is minutely granular.

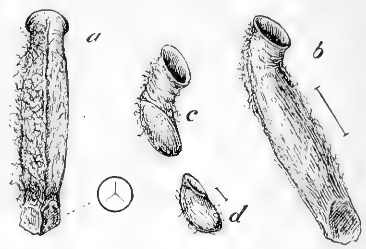


FIG. 9.—The cases of the cigar case-bearer (*Coleophora fletcherella*): *a*, Upper view of the cigar-shaped case, showing the smooth and the hairy sides and the three-lobed hind opening; *b*, side view of same; *c*, the case as it appears in the spring, with the tubelike addition; *d*, the fall and winter case. Much enlarged. (Original.)

The case, as it is made in the fall, is a minute, flattened structure (fig. 9, *d*) composed of portions of the upper and lower skins of the leaf. In the spring, with the growth of the larvæ, the anterior opening is prolonged into a tube made from fragments of leaves fastened by silk (fig. 9, *c*). The second case, in which the larva finally pupates (fig. 9, *a*, *b*), is longer, cylindrical or cigar-shaped, slightly compressed laterally, and with a more or less distinct ridge above and beneath. The anterior opening is round, slightly funnel-shaped, and bent downward, so that the plane of the opening forms an acute angle with the longitudinal axis of the case. The posterior end terminates in three lobes, which neatly close the opening. The average length of the cigar-shaped cases is 6.5 mm. and the width 1.3 mm. They are of a light brownish color, much like that of the dry leaves. As the case is made from the skin of the upper and lower sides of the leaves, the one side is hairy or velvetlike, while the opposite side is almost smooth.

THE PUPA.

The pupa (fig. 10, *b*) has an average length of from 4 to 5 mm. It is light brown, long and slender, terminating posteriorly in a broad, somewhat depressed cremaster, with two short lateral spines on either side; the wing sheaths are narrow, with free, pointed extremities reaching almost to the end of the body: the hind borders of the abdominal segments are smooth; there is a chitinous semiringlike ridge on the anterior portion of the third to seventh abdominal segments. On emergence of the adult, the pupal skin remains within the case.

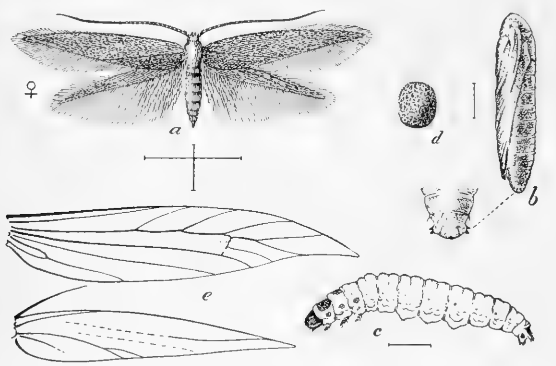


FIG. 10.—The cigar case-bearer (*Coleophora fletcherella*): *a*, Adult female; *b*, side view of pupa and upper view of cremaster of same; *c*, larva; *d*, egg; *e*, venation of fore and hind wings. Much enlarged. (Original.)

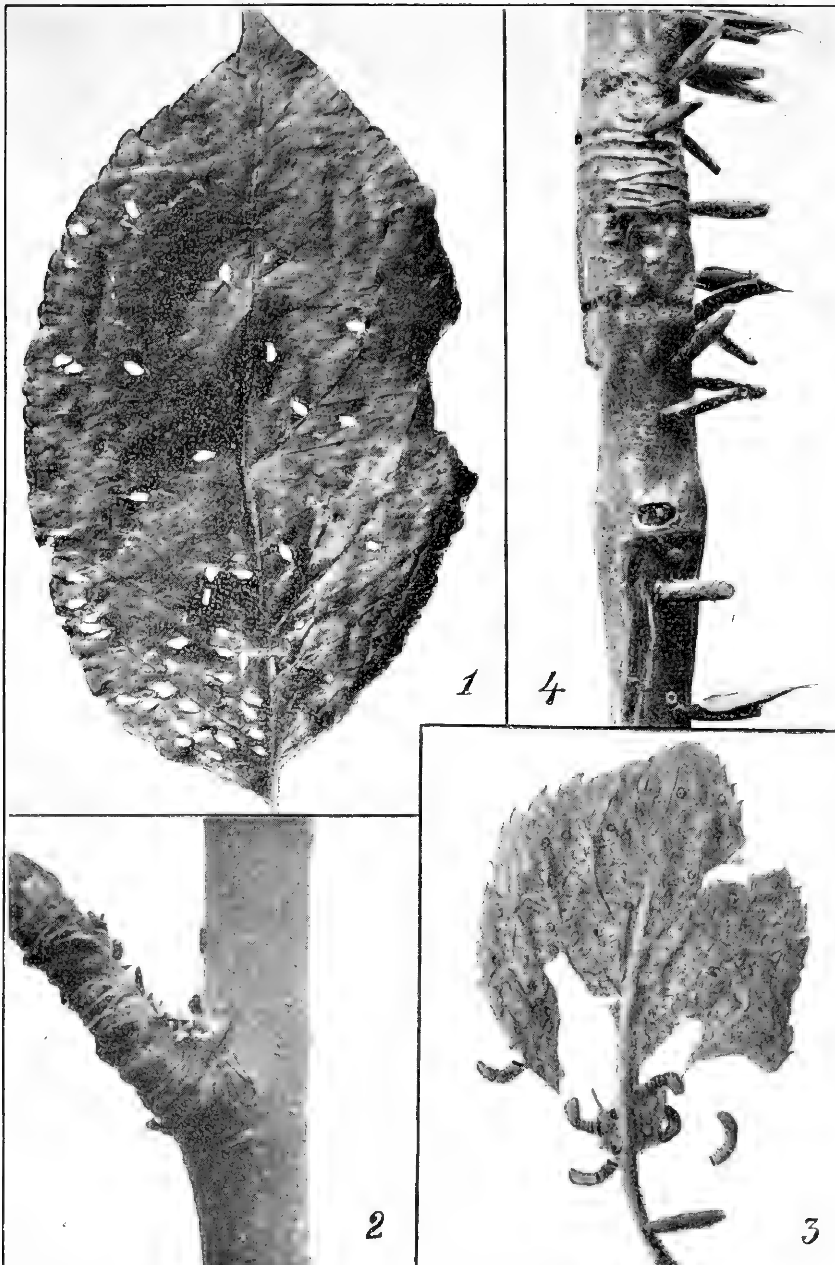
THE MOTH OR ADULT.

The original description of the moth (fig. 10, *a*, *e*), as published by Fernald,[a] is herewith given:

Expanse of wings from 10 to 12 mm. Head, palpi and basal joint of the antennæ, yellowish steel gray. Body, legs and wings above and beneath, plain steel gray, much more intense in fresh specimens. The palpi are without tufts, the basal joint of the antennæ with a slight tuft, and the remaining joints of the antennæ and also the joints of the tarsi are steel gray annulated with white.

The two sexes are similar in color, the male, however, being smaller and recognizable by the blunt termination of the abdomen. The abdomen of the female is larger, more or less spindle-shaped, and terminates in a slender ovipositor, which as a rule protrudes from the last segment. The wings are typically like those of the Tineidæ; narrow, pointed, with the veins in the hind-wings almost obliterated; the hind border of both wings is fringed with long hairs, which are especially pronounced in the hind-wings. On emerging from the pupa the moth assumes a very characteristic pose, as illustrated in Plate II, figure 4.

[a] Can. Ent., 1892, p. 122.



THE CIGAR CASE-BEARER.

Fig. 1.—Apple leaf from which numerous cases have been constructed. Fig. 2.—Overwintering larvæ (enlarged). Fig. 3.—Apple leaf from which cigar-shaped cases have been made, the empty spring cases still adhering (enlarged). Fig. 4.—Newly emerged moths in their characteristic pose on the empty cases. (Original.)

SEASONAL HISTORY.

In the early spring, as the buds begin to open, the minute larvæ free their cases (fig. 9, *d*) from the branches where they have over-wintered, and begin to move about in search of food. Many of them reach the buds before these are opened, and eat into the soft inner tissues. By the time the leaves have begun to expand practically all of them have left their hibernating places and are actively feeding upon the delicate leaves.

With the growth of the larvæ an addition is built to the case in the form of a tube. This extends from the anterior opening on the lower side of the case, and consists of fragments of leaves and silk. (See fig. 9, *c*.)

Fletcher observed that occasionally a larva, on reviving in the spring, would leave its old case and make a new one, but as a rule the old case is detached from its winter resting place and is used for some time before a new one is made.

Toward the middle of May the larva makes a case of an entirely different appearance. After having undermined a sufficiently large area on the leaf, the larva abandons the old case, which usually remains attached to the leaf (Pl. II, fig. 3) and from the upper and lower skins of the leaf cuts out the future case. At first this is of an elongated, somewhat flattened shape, but as it becomes lined inside with silk it assumes a more cylindrical or cigar-shaped form. On close observation it will be found that one side of the case is of a hairy or woolly structure, while the opposite side is smooth. This is readily explained by the fact that the case is made from the upper and lower epidermis of the leaf, the lower surface being hairy and the upper practically smooth. In this case the larva will continue feeding for about one month. During that period it grows rapidly and consumes a relatively large amount of food. The injury caused at this time, though very extensive, is perhaps not more serious than in the early spring, when the opening buds are mutilated or killed by young larvæ.

For some unknown reason it sometimes happens that a larva with a cigar-shaped case will abandon it and make a new one which is apparently similar in all respects to the one previously used. The writer has also observed larvæ transforming in the spring cases. This is probably owing to a lack of food, since these specimens, as a rule, seldom attained their full size. About the middle of June the larvæ cease feeding and migrate from the leaves to the branches. The anterior end of the case is firmly fastened to the branch by means of silk, and a mass of silk is placed in the same end for the attachment of the cremaster of the future pupa. The larva turns around within the case before transforming, so that the head of the pupa is toward the posterior and free end of the case. The opening at this end is closed by three lobes, which are readily pushed apart by the emerging adult. A day or two after the fastening of the case, pupation takes place, and from ten to twelve days later the adult emerges.

At North East, Pa., the first adult emerged June 22; the maximum emergence took place during the early part of July, while after July 25 no adults emerged. As a rule, the adults emerge in the afternoon, and for several hours remain motionless on the case in a characteristic pose, as shown in figure 4 of Plate II. Toward evening they become restless and fly off. Moths even a few days old generally seek their favorite resting place on the attached cases.

The eggs are generally laid along the midrib, on the underside of the leaves, where they are found inserted in the pubescence or down of the leaf. A few eggs were similarly found on the hairy branches. The egg period lasts from fifteen to sixteen days.

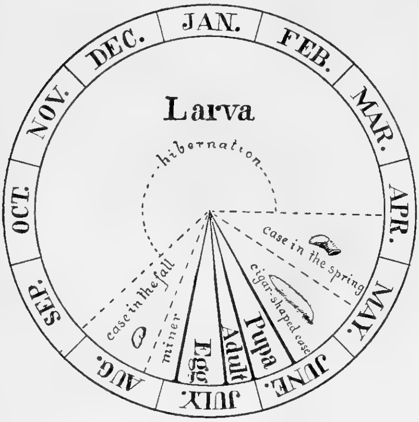


FIG. 11.—Life cycle of the cigar case-bearer: Adapted to a single insect under average normal conditons. (Original.)

The newly hatched larvæ are quite active, and were found moving about for several hours before eating their way into the leaves. During their early life they are true miners and feed for about two weeks on the inner tissues of the leaves. Their mines take the form of minute, elliptical, brown patches, and are readily located by the presence of the black powdery excrement which the larvæ eject from the mines.

Toward the beginning of August the larvæ construct a minute case from the upper and lower skins of the mined area of the leaf. Plate II, figure 1, shows a single leaf from which numerous cases of this kind have been made.

Before the foliage is ready to drop, the minute case-bearers migrate to the branches, where they fasten their cases and seal themselves up for the winter. During the latter part of August and early September they were found in great numbers, especially in the forks and to some extent on the lower side of the branches. (See Pl. II, fig. 2.) For seven months the larvæ remain thus concealed in a dormant state, and, as previously stated, do not become active until spring.

A general idea of the life cycle of the insect may be obtained from the diagram, figure 11. It shows the life cycle of a single insect, the dates and periods shown being averages for the insect as it was observed in its various stages in the field.

ENEMIES.

PARASITES.

Fletcher in 1897 reported a hymenopterous parasite of this insect, *Microdus laticinctus* Ashm., from Port Hope, Ontario.

At North East, Pa., at the time of the emerging of the adults, another hymenopterous parasite, *Habrocytus* sp. (fig. 12), as determined by Mr. J. C. Crawford, was reared in considerable numbers. About 10 per cent of the transforming insects were parasitized.

PREDACEOUS ENEMIES.

The writer found that the eggs of the case-bearer were extensively destroyed by a minute yellow mite, which during the egg period was very abundant all over the orchard. The larvæ of the lacewing fly (*Chrysopa oculata* Say) and various species of ladybird beetles vigorously attacked the eggs and larvæ.

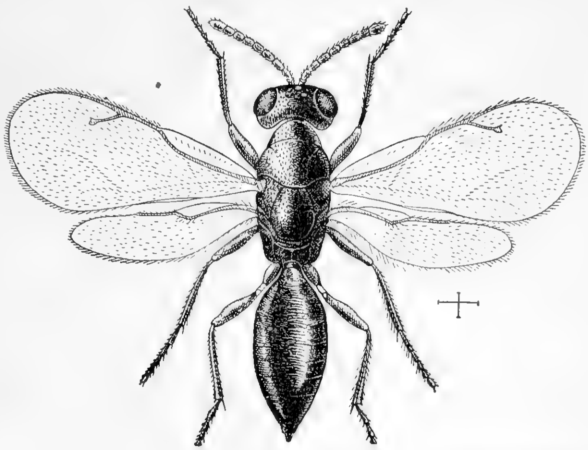


Fig. 12.—*Habrocytus* sp., a parasite of the cigar case-bearer. Greatly enlarged. (Original.)

METHODS OF CONTROL.

A full account of the results of the various spraying experiments carried out in Canada by different fruit growers will be found in Fletcher's report for 1894 as entomologist and botanist for the Canadian experimental farms, pages 201 to 206. It was well demonstrated that the insect can be held under control with either a kerosene emulsion or a Paris green spray applied in the early spring before and while the leaf buds are opening.

In orchards regularly treated with arsenical sprays for the codling moth the cigar case-bearer, if present in orchards, will undoubtedly be kept in check.

BIBLIOGRAPHY.

1889. Lintner, J. A.—*Coleophora* sp.<5th Rep. Ins. N. Y., p. 324.

1890. Lintner, J. A.—*Coleophora* sp. A new pear insect.<Proc. Western N. Y. Hort. Soc., pp. 22–24.

First account of the insect's life history; refers to injury and recommends an arsenical spray.

Lintner, J. A.—*Coleophora* sp. A new pear insect.<Popular Gardening, Buffalo, N. Y., 1890, p. 198.

Same as previous account.

1891. Lintner, J. A.—*Coleophora* sp. A new pear insect.<7th Rep. Ins. N. Y., pp. 347, 361.

Same as above.

1892. Fernald, C. H.—*Coleophora fletcherella*, n. sp.<Can. Ent., vol. 24, pp. 122–123.

Original description of the species.

Fletcher, J.—*Coleophora* sp.<Evidence of the Entomologist and Botanist before the House of Commons, p. 9.

Brief account of its life history and results from spraying.

Fletcher, J.—*Coleophora* n. sp. The cigar case-bearer of the apple.<Exp. Farms [Canada], Rep. Ent. and Bot. for 1891, pp. 196–198.

Further accounts of spraying experiments.

1893. Fletcher, J.—*Coleophora fletcherella* Fernald.<Exp. Farms [Canada], Rep. Ent and Bot. for 1892, p. 4.

Brief mention.

Lintner, J. A.—*Coleophora* sp. on apple leaves.<8th Rep. Ins. N. Y. for 1891, pp. 264, 297.

Lintner, J. A.—*Coleophora* sp.<9th Rep. Ins. N. Y., p. 374.

Brief mention.

1894. Fletcher, J.—*Coleophora fletcherella* Fernald.<Evidence of the Entomologist and Botanist before the House of Commons, p. 19.

Brief mention.

Fletcher, J.—Injurious insects of the year 1894.<25th Ann. Rep. Ent. Soc. Ont., pp. 79–80.

Short account of the life of *C. fletcherella* and its control.

Fletcher, J.—The cigar case-bearer.<Can. Hort., vol. 17, p. 302.

Inquiry about the cigar case-bearer, with reply by Fletcher.

1895. Fletcher, J.—*Coleophora fletcherella* Fernald. The cigar case-bearer of the apple.<Exp. Farms [Canada], Rep. Ent. and Bot. for 1894, pp. 201–206.

Extensive account of spraying experiments.

Bailey, L. H.—The recent apple failures of western New York.<Cornell Exp. Sta. Bull. 84.

Slingerland, M. V.—The cigar case-bearer.<Bull. 93, Cornell Agr. Exp. Sta.

An extensive and good account of the insect, illustrated with photographic reproductions.

1895. WEBSTER, F. M.—Ohio Farmer, June 27, 1895, p. 503, 3 figs.

A summarized account of the cigar case-bearer with special reference to Cornell Experiment Station Bulletin 93.

1896. COCKERELL, T. D. A.—*Coleophora fletcherella* Fernald.<Bull. 19, N. Mex. Agr. Exp. Sta., p. 117.

Introduced into New Mexico on infested nursery stock from New York State.

FLETCHER, J.—Insect injuries of the year 1895.<26th Ann. Rep. Ent. Soc. Ont., p. 37.

Mention of *C. fletcherella* Fernald.

FLETCHER, J.—The cigar case-bearer of the apple.<Can. Ent., vol. 28, No. 5, pp. 128–130.

A brief account of the insect; reference to Slingerland's work.

FLETCHER, J.—The cigar case-bearer (*Coleophora fletcherella* Fernald). <Exp. Farms [Canada], Rep. Ent. and Bot. for 1895, pp. 153–155.

Further spraying experiments.

1897. FLETCHER, J.—The cigar case-bearer (*C. fletcherella* Fernald).<Exp. Farms [Canada], Rep. Ent. and Bot. for 1896, p. 252.

A brief note of results of kerosene emulsion spray.

FLETCHER, J.—*Coleophora fletcherella* Fernald.<27th Ann. Rep. Ent. Soc. Ont., p. 67.

Parasite: *Microdus laticinctus* Ashm.

BETHUNE, C. J. S.—Notes on insects of the year 1896.<27th Ann. Rep. Ent. Soc. Ont., p. 57.

Mention of *C. fletcherella* Fernald.

LOWE, V. H.—Inspection of nurseries and treatment of infested nursery stock.<Bull. 136, N. Y. Agr. Exp. Sta., Geneva.

Mention of *C. fletcherella* Fernald.

1898. FAVILLE, E. E.—The cigar case-bearer.<The Industrialist, April, 1898, pp. 271–275, 7 figs.

An account of its occurrence at Manhattan, Kans., life history, mode of control.

1899. BEACH, S. A., V. H. LOWE, F. C. STEWART.—Common diseases and injurious insects to fruits.<Bull. 170, N. Y. Agr. Exp. Sta., Geneva, pp. 381–445.

Brief description of *C. fletcherella* and life history.

1900. FORBES, S. A.—The cigar case-bearer.<21st Rep. State Ent. Ill., p. 146.

Not *C. fletcherella* Fernald, as reported.

FELT, E. P.—Illustrated descriptive catalogue of some of the more injurious and beneficial insects.<Bull. 37, N. Y. State Mus., Vol. VIII, pp. 8–9.

Brief note on *C. fletcherella* Fernald.

1901. FELT, E. P.—The cigar case-bearer.<Country Gentleman, November 7, p. 902.

Brief account of the insect.

FLETCHER, J.—*Coleophora fletcherella* Fernald.<Bull. 37, Cent. Exp. Farm, Ottawa, Can., p. 72.

Brief mention.

1902. BANKS, N.—Principal insects liable to be distributed on nursery stock.<Bull. 34, n. s., Div. Ent., U. S. Dept. Agr., p. 38.

Brief mention.

1903. LOCHHEAD, W.—A key to orchard insects.<33d Ann. Rep. Ent. Soc. Ont., pp. 104, 105, 108.

Brief mention of *C. fletcherella* Fernald.

1904. BALKWILL, J. A.—Report on insects of the year.<34th Ann. Rep. Ent. Soc. Ont., p. 20.

Brief mention of *C. fletcherella* Fernald.

PETTIT, R. H.—Insects injurious to fruits in Michigan.<Spec. Bull. 27, Mich. Agr. Exp. Sta.

Brief note on *C. fletcherella* Fernald.

O

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part III.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

ADDITIONAL OBSERVATIONS ON THE LESSER APPLE WORM.

BY

S. W. FOSTER AND P. R. JONES,

Engaged in Deciduous Fruit Insect Investigations.

ISSUED AUGUST 12, 1909.

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ADDITIONAL OBSERVATIONS ON THE LESSER APPLE WORM.

(*Enarmonia prunivora* Walsh.)

By S. W. Foster and P. R. Jones,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

The prevalence of the lesser apple worm throughout the apple-growing districts of the United States east of the Rocky Mountains, as was pointed out by this Bureau in 1908, has awakened considerable interest among apple growers and others, and as the insect has become better known its importance as a pest is more fully realized. Especially noticeable is the late fall injury caused by the later broods, some of the larvæ of which work in the fruit for weeks after the crop is harvested.

The principal purpose of the present paper is to record additional information on the life history and habits [a] of the insect, and to give a description of the egg, which was first observed during the summer of 1908, both at Siloam Springs, Ark., and in the insectary of the Bureau of Entomology, at Washington, D. C.

It is also desirable to separate, in so far as possible, the injurious work of the lesser apple worm from that of a larva of another species which closely resembles it, and which latter feeds on the twigs as well as the fruit at certain seasons of the year.

All life-history studies were made under normal out-of-door conditions. The senior author, with the cooperation of Mr. E. L. Jenne, made the observations at Siloam Springs, Ark., and the junior author, who also furnished the description and photomicrograph of the egg, conducted the observations at Washington.

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[a] The history, distribution, and character of injury of this species have been fully given by Mr. A. L. Quaintance in Bul. 68, Part V, of this Bureau, and reference to these points will be omitted here.

TWO APPLE CATERPILLARS OTHER THAN THE CODLING MOTH.

Early in the season of 1908 it was noticed that another small larva, the adults of which emerged from June 15 to 25, resembling very closely that of *Enarmonia prunivora*, was feeding in the apples and plums around Siloam Springs, Ark. Later in the season, July and August, adults were reared in numbers from larvæ found in young vigorous growing shoots and water sprouts of apple trees. Most of the injury to the twigs, however, was done in June and July.

The many observations by the writers would indicate that a large part of the first-brood larvæ matures in the fruit; that the remainder of the first brood and also the second brood mature in the young twigs and water sprouts; and that the larger part of the later brood goes back again to the fruit. Adults were secured from fruit from June 5 to 20. After June 23 no more specimens were reared from fruit until August 17, while during this period many adults were reared from the twigs. After August 10 to 15 there was a marked decrease in the twig injury and an increase in fruit infestation. Beginning August 17, many adults were reared from apples throughout the remainder of the season. Adults of this species were determined by Mr. August Busck as *Epinotia pyricolana* Murtf., and its injuries to fruit have not apparently been heretofore recorded. This species has been treated by Prof. E. D. Sanderson in the Twelfth Report of the Delaware College Agricultural Experiment Station (1900) pages 194–199.

During the season the writers were unable to obtain a single specimen of *Enarmonia prunivora* from twigs of the apple, but all specimens taken proved to belong to *Epinotia pyricolana*. In the Ozark region and also in the vicinity of Washington, D. C., this species is far less abundant than either the codling moth or the lesser apple worm.

COMPARATIVE ABUNDANCE OF THE LESSER APPLE WORM AND THE CODLING MOTH IN APPLES.

The injury caused by the lesser apple worm early in the season is not so pronounced, nor are the larvæ so abundant as those of the codling moth, but by midsummer and fall there is a marked increase in the number of larvæ of this species over that of the codling moth. This increase is often sufficient to bring the total number of lesser apple worms, in the fruit for the season, in excess of the codling-moth larvæ.

Records were kept of the comparative abundance of the two species by bringing in during the season infested fruit from unsprayed orchards and keeping the infested fruit collected on different dates in separate breeding cages. Each lot was examined daily for full-grown larvæ and adults.

Table I gives the relative number of the two species as obtained from wormy apples picked from the trees, each picking including some windfalls, which would tend to slightly increase the percentage of Enarmonia larvæ.

TABLE I.—*Relative seasonal increase of Enarmonia prunivora over codling moth larvæ in windfalls and in fruit picked from trees in orchard of D. S. Ballou, Siloam Springs, Ark., 1908.*

Quantity of apples.	Date collected.	Number specimens of Enarmonia and Epinotia.[a]	Number specimens of codling moth.	Percentage Enarmonia and Epinotia larvæ.[a]
1 gallon	May 14	4	6	40
½ gallon	May 26	11	25	30.5
2 gallons	June 8	21	61	25.6
2½ gallons	June 30	15	22	40.5
3 gallons	July 16	84	24	77.8
3 gallons	Aug. 4	120	53	59.3
4 gallons	Aug. 22	62	17	78.5

[a] Enarmonia and Epinotia larvæ were not separated in Tables I and II, as it was not possible to readily distinguish between them. However, there were very few specimens of Epinotia till late in the season, i. e., after the middle of August, and then in small numbers as compared with the number of Enarmonia.

Table II, prepared by Mr. E. L. Jenne, is from wormy fruit picked from trees at intervals stated, no windfalls being included.

TABLE II.—*Relative seasonal increase of Enarmonia prunivora over the codling moth in fruit picked from trees, Flickenger orchard, Siloam Springs, Ark., 1908.*

Number of apples.	Date collected.	Number specimens Enarmonia and Epinotia.[a]	Number specimens of codling moth.	Percentage Enarmonia and Epinotia larvæ.[a]
139	May 26–7	6	80	7.0
56	June 20	10	28	26.3
58	June 30	17	22	43.6
64	July 16	17	27	38.6
156	July 31	44	77	35.4
129	Aug. 16	95	54	63.8
107	Sept. 1	95	39	70.9

[a] See footnote to Table I.

SEASONAL HISTORY AND HABITS.

Information regarding the overwintering or hibernating habits of the larva of this insect is not yet complete. Overwintering larvæ have been found in cracks and crevices of the bark of trees, and also in fruit and barrels which had been stored over winter. Searching through the rubbish around the apple bin of a vinegar factory on March 24, Mr. E. L. Jenne and the writer found larvæ of Enarmonia at the rate of 4 to 135 larvæ and pupæ of the codling moth. A few days later 234 larvæ and pupæ of the codling moth located from 3 to 8 feet above ground were collected from the framework of the same apple bin. No larvæ or pupæ of Enarmonia were found. Larvæ have been found in great abundance in late fall in the partly devoured fruit of Cratægus, both on the trees and on the ground. Many larvæ passed the winter in this fruit in our breeding jars, and this overwintering habit very probably obtains under natural conditions. (See Pl. III, fig. 2.)

From many observations on larvæ in fruit during the winter months, the difficulty of rearing moths in spring from overwintering material and the very light infestation of orchards by the first-brood larvæ point to a high mortality among the larvæ during the winter.

Moths from overwintering larvæ of Enarmonia emerge about the same time as those of the codling moth. At Washington, D. C., moths emerged in 1908 from April 26 to 28 and during the first few days of May from quantities of Cratægus berries which had been kept out of doors in jars and cages over winter. Mr. Jenne secured adults April 18 to 30, 1909, from overwintering larvæ at Siloam Springs, Ark. Other moths emerged May 1, 7, and 9, 1909.

At Washington, during the spring of 1909, moths emerged from the fruit of Cratægus maintained under out-of-door conditions as follows: April 6, 1; April 24, 3; April 26, 6; April 29, 3; April 30, 4; May 1, 6; May 3, 6; May 4, 9; May 7, 14; May 10, 29; May 12, 9; May 14, 7; May 17, 1; May 18, 3; May 22, 2; May 25, 3; May 26, 1; and May 28, 1, which was the last individual to appear.

In the Ozark region the first brood of larvæ matures usually during the month of June; moths for the second-brood larvæ emerged in 1908 from June 20 to July 30. Eggs deposited in breeding cages by these moths July 10 to 12 produced full-grown larvæ July 30 to August 10, the adults emerging August 14 to 26. Eggs from these latter gave another brood of full-grown larvæ September 19 to 30. Other adults, emerging later, deposited eggs as late as September 7 to 14, the full-grown larvæ leaving the fruit October 3 to November 6, when observations ceased, some larvæ being still at work in fruit.[a] This is strong evidence of three full generations annually for the Ozark region. Since many moths had emerged from first-brood larvæ before July 10 to 12, when the above individual records began, it is possible that some of the earlier ones emerged in time to give rise to a partial fourth brood of larvæ.

LIFE CYCLE AND DURATION OF STAGES.

THE EGG.

Individual records kept for 120 eggs during July, August, and September gave the minimum time of incubation as four and one-sixth days and the maximum five and one-half days. Most of the eggs

[a] Moths emerged as late as September 26, but no records were kept of eggs deposited after September 14.

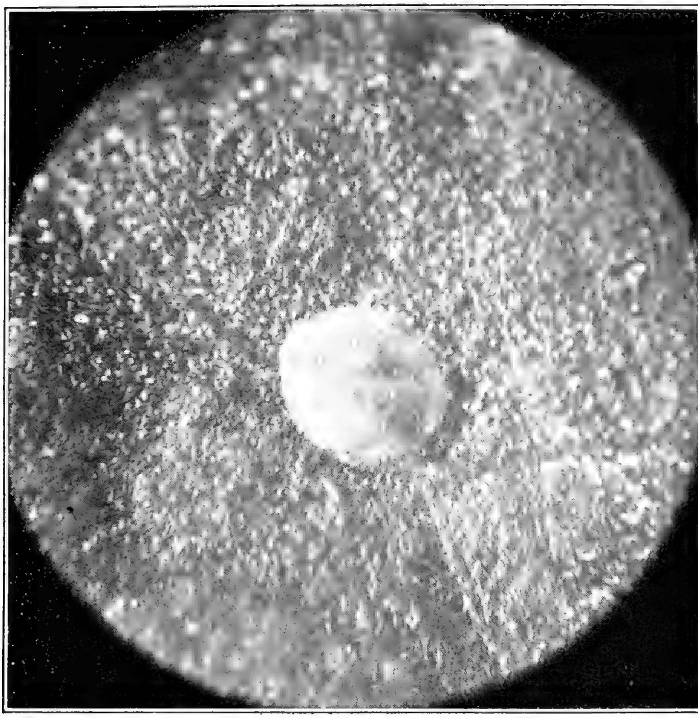

FIG. 1.—PHOTOMICROGRAPH OF EGG OF LESSER APPLE WORM (ENARMONIA PRUNIVORA). (ORIGINAL.)

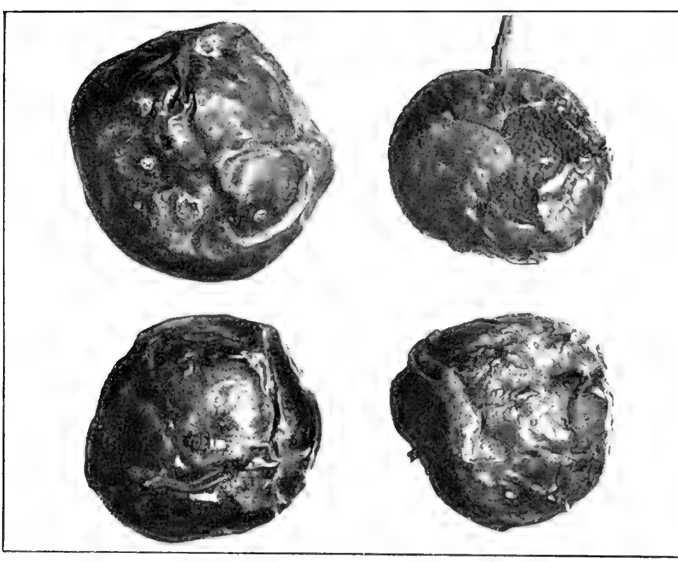

FIG. 2.—WORK OF LESSER APPLE WORM ON FRUIT OF CRATÆGUS. TWICE ENLARGED. (ORIGINAL.)

hatched between one hundred and six and one hundred and twenty-four hours after deposition, the average being slightly more than five days.

The following table of group records taken from batches of eggs deposited on sides of breeding cages and on apple foliage kept inside of cages shows the approximate time of incubation:

TABLE III.—*Period of incubation of eggs of Enarmonia prunivora under normal out-of-door conditions, Siloam Springs, Ark., 1908.*

Number of eggs.	Date deposited, night of—	Black spot appeared.	Egg hatched.	Time.
				Days.
7	Aug. 28	September 2, m	September 3, a. m	$5\frac{1}{4}$
3	Aug. 29	September 3, a. m	September 4, a. m	5
1	Sept. 6	September 11, a. m	September 12, a. m	$5\frac{1}{4}$
5	Sept. 7	September 12, m	September 13, a. m	$5\frac{1}{2}$
11	Sept. 9	September 13, p. m	September 15, a. m	$5\frac{1}{4}$
11	Sept. 11	September 16, a. m	September 16, p. m	$5\frac{1}{4}$
35	Sept. 12	September 17, a. m	September 17, p. m	$4\frac{1}{2}$–$5\frac{1}{4}$
			September 19, a. m	$4\frac{1}{2}$–$5\frac{1}{4}$
4	Sept. 13	September 18, p. m	September 19, a. m	$5\frac{1}{4}$
6	Sept. 14	September 19, p. m	September 20, a. m	$5\frac{1}{4}$

THE LARVA.

The length of the larval period from time of hatching to leaving fruit varied from thirteen to fifteen days during July, from twenty to twenty-seven days in August and the first half of September, and increased to from thirty to fifty days after the middle of September to early November.

Individual records for over 100 larvæ show a minimum of thirteen days and a maximum of fifty days for actual time in fruit of normal healthy larvæ which left fruit prior to November 6.

THE LARVA IN COCOON BEFORE PUPATING.

This period varies greatly, according to where the larva is kept, being much longer when confined with bits of paper, etc., in glasses. From about 100 specimens allowed to spin cocoons in ends of apples, either at the stem or blossom end, the average time during the months of July and August was seven to eight days from leaving the fruit to pupation, the minimum being one day and the maximum twelve days.

THE PUPA.

The actual duration of the pupal stage varies from a minimum of four (?) to a maximum of seventeen days, averaging about ten days. Seventy-four per cent of all pupæ observed in Arkansas developed moths in between eight and twelve days. The records in Washington agree very closely with those in Arkansas.

The total time in the cocoon, from the date of full-grown larvæ leaving the fruit to the emergence of the moths, varies from thirteen to thirty days, although normally it is about seventeen days. Seventy per cent of all moths emerged between thirteen and eighteen days after the larvæ left the fruit.

Taking the normal or average figures for each stage, the complete life cycle requires approximately six weeks, but many individuals complete the life cycle in thirty days in early summer. During the period from August to October some individuals required as high as forty to fifty and a few to sixty days.

DESCRIPTION OF EGG.[a]

Egg: Size, 0.53 to 0.70 mm. long by 0.51 to 0.55 mm. wide; oval in outline, varying to roundish, slightly convex, and covered with a network of irregular ridges. At time of deposition it is pearly white, and resembles very closely in general appearance the egg of the codling moth, except for its smaller size, the ridges being somewhat closer together and not so prominent as with the latter. (See Pl. III, fig. 1.)

The eggs assume a yellowish cast one or two days after deposition, shortly after which a red ring appears; the black head of the larva usually appears in four days.

Moths confined in rearing cages deposited eggs on both sides of the leaves, but mostly on the upper surface on the fruit, stems, and on the glass door and wooden uprights of the rearing cage.

PARASITES.

Only one parasite is recorded in literature from this species, viz, *Mirax grapholithæ* Ashm. During the past season a specimen was reared from a larva infesting apple, which has been determined by Mr. H. L. Viereck as *Phanerotoma*, n. sp.

CONTROL MEASURES.

The usual treatment practiced against the codling moth has so far served to very effectively keep in check serious injury by this species.

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[a] Since this paper was submitted for publication the egg stage has been well described by E. P. Taylor in Journ. Econ. Ent., June, 1909, p. 237.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part IV.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE PEAR THRIPS AND ITS CONTROL.

BY

DUDLEY MOULTON,

Engaged in Deciduous Fruit Insect Investigations.

Issued September 1, 1909.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE PEAR THRIPS AND ITS CONTROL.[a]

(*Euthrips pyri* Daniel.)

By Dudley Moulton,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

Cultivation and spraying, the principal treatments involved in the control of the pear thrips, are largely subject to suitable weather conditions, and each, to be effective, must be accomplished at its proper time. Other orchard work, such as irrigation, cultivation, pruning, and spraying for other insect and fungous troubles, must therefore be considered well beforehand and completed or so arranged that nothing will interfere with the treatment for the thrips. It is highly important that the individual orchardist should have everything in readiness to treat his own orchard at exactly the right time. Preparedness for and thoroughness in the work of spraying and in plowing, it will be found, are the most important factors in the successful control of this insect.

DISTRIBUTION.

The pear thrips is known to occur only in the central part of California, and especially in localities in the general neighborhood of the San Francisco Bay. Reports of its ravages have been received from the Sierra Nevada foothills, near Newcastle and Auburn, and from the

[a] The control of the pear thrips has been for several years the principal problem confronting the growers of deciduous fruits in portions of central California. This insect, on account of its mode of attack and habits, has presented unusual difficulties in control. It is believed, however, that the investigations of the Bureau of Entomology have now determined practical and efficient measures which, if carefully followed out by orchardists, will insure its reduction below injurious numbers. The investigation has involved a large amount of detailed study of the insects' behavior on the trees and in the ground, and the testing of a large series of spray mixtures, fertilizers, soil fumigants, etc. Mr. Moulton has been continuously engaged in the work for the past three years, assisted a part of the time by Messrs. Charles T. Paine and P. R. Jones. Beginning with the spring of 1909, Mr. S. W. Foster was charged with the operations in Contra Costa County and northward, Mr. Fred Johnson collaborating during the spring months. The present is the second report upon the pear thrips, the first, published as Part I of Bulletin 68 of this Bureau, dealing largely with the insect's life history and habits.—A. L. Quaintance.

Tulare and Fresno fruit districts, but it was found after a careful investigation that none of these fruit areas was infested. In the one case, at Newcastle, the injury was evidently that of the blossom pear-blight and not a single pear thrips could be found in the whole region at a time when the insects should have been in evidence in greatest numbers. A few thrips of another species (*Euthrips occidentalis* Pergande) were found in pear and cherry blossoms in this locality, but this insect is not injurious to fruits, and its presence in blossoms is of no consequence. Thrips from pear blossoms at Visalia were found to be of the species *Euthrips tritici* Fitch, which also is not usually injurious to fruit trees. The present infestation, then, is confined to the region around and closely adjoining the San Francisco Bay. It extends south through the Santa Clara Valley and into Hollister, San Benito County, north through Alameda, Contra Costa, Solano, and Yolo counties, and also occurs in some rather small areas along the Sacramento River. The area of deciduous fruits, about 60,000 acres, in the Santa Clara Valley, is practically all more or less infested by the thrips; and the other infested orchard sections, such as Hollister, Walnut Creek, and Concord, in Contra Costa County, and Suisun and Vaca orchards and others along the Sacramento River, also include many hundreds of acres.

The original home of this species is still in doubt. Several men have expressed the opinion that it is of European origin, but, according to Doctor Buffa, the insect does not occur in Europe, and after examining the species he believes it to be of eastern origin, suggesting China as possibly its original home.

The various thrips which are seen in roses and in other flowers, and which can be found at almost any time of the year, should not be mistaken for the pear thrips, which is distinctly a fruit-tree pest and does not attack grass, weeds, or cultivated flowers. It has, once or twice, been collected from leaf clusters of rose bushes, but this is not common. The name "pear thrips" was given because the insect was first found in pear blossoms, but this does not indicate that it attacks pear trees only. The injury on prunes and other fruit trees is equally as serious as that on pears. Thrips should not be confounded with the vine hopper *Typhlocyba comes* Say, an insect which is wrongly called "thrips," but is not a thrips at all. The term "thrip," so commonly used, is also erroneous, as the word "thrips" is both singular and plural.

CHARACTER OF INJURY.

FEEDING INJURY BY ADULTS.

Adult thrips appear on trees during late February and early March, when the buds are just beginning to open (Pl. IV). They remain on the tree until late in April and are thus feeding all through the period of the early opening of buds, of blossoming, and of the unfolding of leaves and the setting of fruit. They come to the trees ravenously hungry after a long fast of ten or eleven months in the ground, and they force an entrance as soon as possible into the first opening buds. Their habit of getting inside immediately has led many orchardists to believe that they in some mysterious way gain entrance into the buds before these are opened. This is not the case, as the insects never enter until after the buds are swollen and partly or wholly opened at the tips. They do not feed on the tough tissues of the bark or on the outer bud scales, but wait until they can get inside. When thrips are very numerous these early buds either never open at all or form only weak blossoms, which present the appearance of having been burned (Pl. V, fig. 1). Thrips will usually migrate in search of new food plants after the blossoms are thus completely destroyed, which explains, in part at least, why they may temporarily disappear from a given orchard or part of an orchard, where perhaps a few days previous they had been numerous enough to destroy the entire crop. When thrips are less numerous the injury is accumulative, but it may finally prove as serious as when many more thrips are present. A few individuals may continue to feed within clusters for days or even weeks. The growth of the tree is then retarded and its blossoms and leaves become weak and deformed. Trees may produce a heavy bloom, even where many thrips are present, but the blossoms and leaf stems will be scarred, weakened, and abnormally short and the fruit does not set. This is especially true of prunes. A few adult individuals may feed in a cluster of pear blossoms, and although the buds drip with exuding sap and are moldy, many if not all of these pears may set and there may follow a heavy crop of fruit, but always in such cases the fruit is ill shaped and badly scabbed. The scabbing on pears (Pl. V) is accomplished almost entirely by adults which feed within the clusters of buds, while scabbing of prunes (Pl. VI) is done almost entirely by larvæ which feed on the fruits under protection of the old calices before these are sloughed off.

Injury by adults in almonds, apricots, and peaches is not serious unless very many individuals are present. These trees bloom rather early, and since each blossom comes singly in a bud, there is offered almost no opportunity for the thrips to get inside until the blossom itself is well opened, whereupon the thrips feed mostly on the nectar glands inside the calyx. This part of the blossom can accommodate quite a few thrips without receiving serious injury, and also the insect is diverted from feeding on the more vital parts. There follows serious injury on these fruits only when many waiting individuals enter the buds and feed on the outside of the little calyx cups and the stems immediately after the winter protecting scales are opened. This group, comprising the almond, apricot, and peach, in which each bud produces but a single blossom, is noticeably less seriously affected by thrips than the group which includes the pear, prune, and cherry, where each bud opens to form a cluster of blossoms. The thrips are admitted into the buds of the latter group immediately upon the spreading of the winter scales and they feed on the outside of the tender blossoms, so that these are weakened before they have a chance to bloom.

Thrips in feeding do not bite off and take internally particles of the outer plant tissue, but tear open the outer layers of plant tissue and, inserting the tips of their mouth-cones, suck up the juices of the plant. This manner of feeding may penetrate through the very young, tender leaves so that later, when the injured parts fall away, the leaves become ragged and full of holes. On very young fruits this feeding injury penetrates through the epidermal layers into the flesh and forms a scab, but on more mature leaves and fruits, where the outer tissues are strong and thick, the effect is that of "silvering."

The relative periods of the spreading of buds and blossoming of the several varieties of fruits are important factors as related to the injury which they receive by adult thrips. Of cherry, the following varieties spread their buds and blossoms in the order named: Republican, Black Bigerreau, Black Tartarian, Royal Ann, and Bingo; and of plum, Japanese plum, and Imperial, Sugar, and French prunes. Such trees as almonds, which blossom very early, or as the Royal Ann cherry, which blossoms late, are not as a rule seriously affected.

The budding and blossoming of fruits in the San Jòse district is as follows: Almond buds begin to swell during the latter part of January and early February, and this variety of fruit is in full bloom between February 8 and 24. Apricots show first blossoms from February 19 to 23, and most varieties are in full bloom by from March 3 to 10. Peaches show first blossoms about February 23, and many varieties are in full bloom by from February 8 to March 17. Black Tartarian cherries reach full bloom by March 20, while the Royal Ann variety has not at that time opened its buds. French prune buds are beginning to swell between March 8 and 11 and first blossoms appear by March 20. They are in full bloom from March 26 to April 8. The Sugar and Imperial varieties precede the French by about one week. Bartlett pears begin to open their clusters from about March 12 to 15 and are in full bloom for quite an indefinite period from March 20 to April 10. Pears, prunes, and cherries which are spreading their buds just after the maximum number of thrips are coming from the ground, are the varieties most subject to injury.

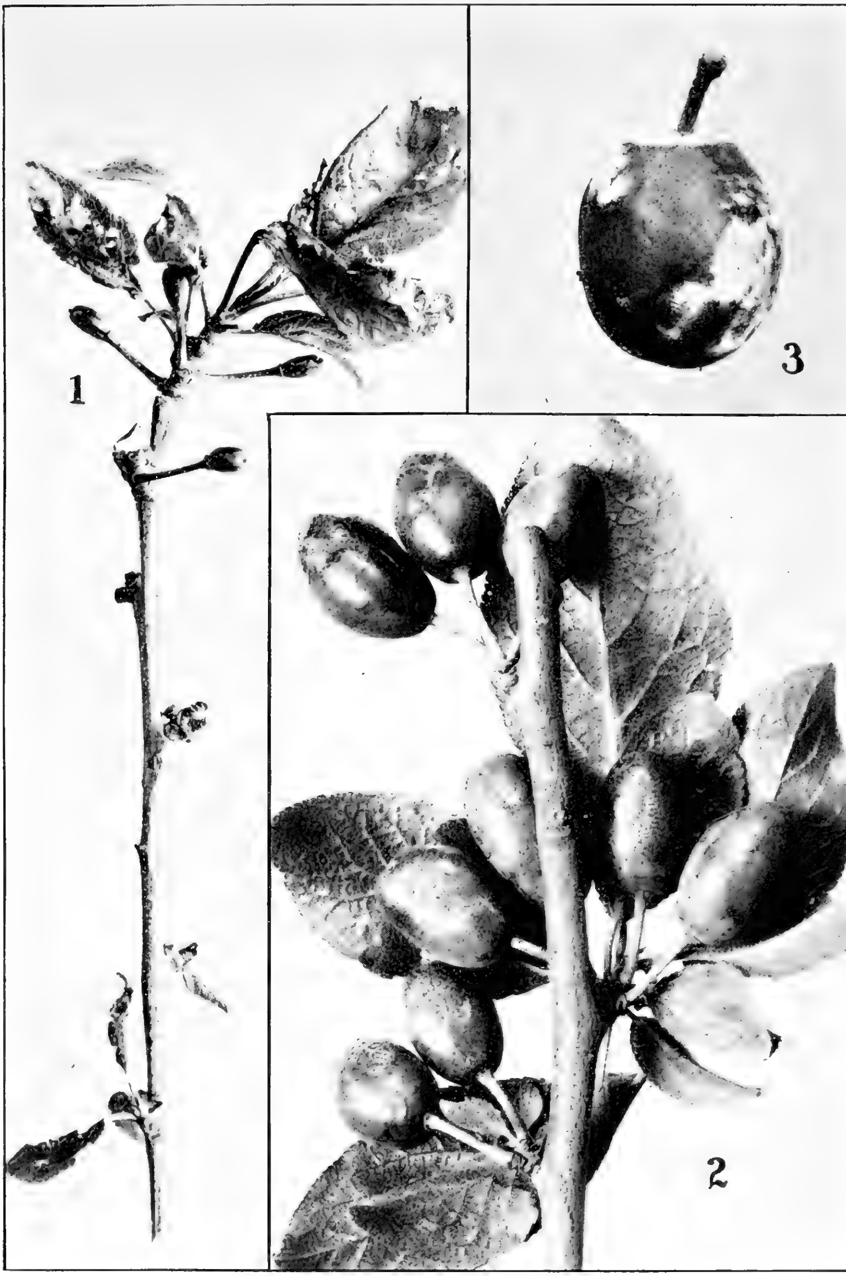
CONDITION OF BUDS AT THE TIME WHEN FIRST SPRAYING FOR THE PEAR THRIPS (EUTHRIPS PYRI) SHOULD BE GIVEN.

Fig. 1.—Bartlett pear. Fig. 2.—French prune. Fig. 3.—Imperial prune. (Original.)

FIG. 1.—DESTRUCTION OF BUDS AND BLOSSOMS. (ORIGINAL.)

FIG. 2.—SCABBING OF FRUIT FROM FEEDING PUNCTURES BY ADULTS ON THE OPENING BUDS IN SPRING. (ORIGINAL.)

WORK OF PEAR THRIPS ON PEAR.



WORK OF THE PEAR THRIPS ON FRENCH PRUNE.

Fig. 1.—Shoot on which crop has been largely destroyed in blossom stage. Fig. 2.—Young fruit, natural size, showing scabbing resulting from work of larvæ. Fig. 3.—Mature fruit showing scabbing injury, resulting in a low grade of dried fruit. (Original.)

The period of blossoming for similar varieties in Contra Costa County is about the same as that in the Santa Clara Valley, while the orchards in the Vaca and Suisun valleys and along the Sacramento River may be a very few days earlier.

INJURY TO TREES BY OVIPOSITION.

The adult female is equipped with a pointed and curved, sawlike ovipositor (fig. 13), by means of which deep cuts are made, into which the eggs are placed well down into the tissues of the plants, mostly in the stems of blossoms or leaves or into the leaf tissue. A single incision is minute and in itself does little harm, as the wound soon heals over, but the tiny stems of the blossoms or of newly setting fruits and the leaf petioles are unfortunately preferred by the insect for ovipositing situations, so that many incisions are often cut into a single stem, which, becoming greatly weakened, turns yellow and the fruit falls. This injury becomes very noticeable at times on the prune and cherry and is undoubtedly the cause of much dropping of immature fruit.

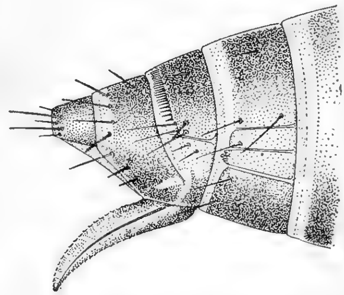


FIG. 13.—The pear thrips (*Euthrips pyri*): Ovipositor and end of abdomen from side. Much enlarged. (Author's illustration.)

INJURY BY LARVÆ.

Thrips larvæ are wingless, never of their own accord traveling from the host plant on which they are born, and usually do not move far from the immediate locality where they have issued from the egg. They seek some sheltered place within a cluster of leaves, in blossoms, or under the protection of the drying calices of such fruits as prunes or cherries. Larvæ are found mostly during the last of March and in April and their injury is distinctly on leaves and fruits and not in opening buds. To them must be attributed almost all the scabbing on prunes (Pl. VI, figs. 2, 3), some silvering on apricots and peaches, and most of the deformed, ragged, and partly dead leaves. This injury to the foliage greatly stunts and weakens a tree if it is repeated during several successive years.

SEASONAL HISTORY AND HABITS.

APPEARANCE OF ADULTS FROM SOIL IN SPRING.

The following table shows clearly just when the first adult thrips are leaving the ground, when in maximum numbers, and when the last individuals are appearing. The figures here represent the total number of thrips collected from four cages from each of four orchards in the Santa Clara Valley, namely, the Landon, Bogen, Sorosis, and Hume orchards. The cages each contained a solid block of earth 17 by 17 inches square, representing a surface area of 2 square feet and a depth of 18 inches, below which thrips have never been found. These cages were removed from under prune and pear trees in the several orchards, brought to the laboratory yard, and again embedded in the ground to their usual depth and covered with a special cage. A daily record was made of the thrips issuing from each cage.

TABLE I.—*Records of emergence from soil of adult pear thrips from four orchards in the Santa Clara Valley, California, spring of 1909.*

Date.	Number of thrips in four cages.				Total.	Date.	Number of thrips in four cages.				Total.
	From Landon orchard.	From Bogen orchard.	From Sorosis orchard.	From Hume orchard.			From Landon orchard.	From Bogen orchard.	From Sorosis orchard.	From Hume orchard.	
1909.						1909.					
Feb. 15	18	0	0	0	18	Mar. 11	13	47	128	310	498
16	0	0	0	0	0	12	12	62	81	183	338
17	51	0	0	1	52	13	18	101	87	207	313
18	176	8	4	4	192	14	1	53	70	124	248
19	160	14	4	14	192	15	3	71	76	129	279
20	126	17	12	14	169	16	1	59	74	125	259
21	60	1	0	14	75	17	3	31	36	72	152
22	84	10	7	18	119	18	1	15	13	13	42
23	106	5	7	17	135	19	8	12	22	19	61
24	403	26	50	73	552	20	1	6	3	18	28
25	301	35	49	74	459	21	0	1	1	0	2
26	320	25	35	64	444	22	2	0	2	2	6
27	232	19	28	134	414	23	0	3	3	7	13
28	372	74	80	255	781	24	0	0	0	3	3
Mar. 1	340	109	114	218	781	25	0	0	0	2	2
2	104	54	92	285	535	26	1	0	1	1	3
3	300	188	258	553	1,299	27	0	0	4	3	7
4	191	104	115	304	714	28	0	0	0	7	7
5	37	93	109	269	508	29	0	0	0	0	0
6	26	34	87	215	362	30	1	1	0	0	2
7	13	50	60	315	438	31	0	0	0	0	0
8	9	38	14	158	219	Apr. 1	0	0	0	3	3
9	18	89	77	602	776	2	0	0	0	0	0
10	18	114	109	256	497	3	0	0	1	0	1

The first adult thrips were collected on February 15, but a very few individuals had been found in blossoms previous to this time. On February 18 they were numerous in one of our experiment orchards, and by February 25 they were common in all orchards. Maximum emergence begins about February 19 and continues until about March 16, a period of three and one-half weeks. A few straggling individuals continued to come out during all the latter part of March and a very few even in April. Practically all thrips, however, are out of the ground by March 20.

The emergence period for thrips in orchards in Contra Costa and Solano counties seems to be three or four days earlier and this will probably hold true also for orchards along the Sacramento River.

MIGRATION OF ADULTS.

The migration of adult thrips is as yet only imperfectly understood. They have wings and are free to fly if they choose, but weather conditions and food supply influence very decidedly their inclination to move about. The tendency is for the thrips to remain quite closely with the trees wherever there are only a few individuals and where the supply of food is abundant. They then fly up during the warm, quiet parts of the day, but do not travel far. It often happens that the insects are so numerous as to kill the early buds or to so injure them that these become brown and dried and do not offer suitable food; the thrips then migrate to other less affected orchards. This migration often occurs before the period of oviposition begins, in which case no new brood is started to infest such an orchard during the following year. This explains why thrips may injure an orchard during one season and seem to have almost entirely disappeared from it the next. This occurrence has led some orchardists to believe that eventually the thrips may move away permanently or die out. This supposition is not correct, and it will be only a matter of a year or two until these orchards will again be attacked.

FIG. 14.—The pear thrips: Eggs. Highly magnified. (Author's illustration.)

Migration, then, occurs only during warm, clear weather and is hastened by a desire for better food or for suitable conditions for ovipositing. Thrips locally do not travel in any particular direction, such as south, or east, or west, but distribute themselves generally wherever conditions are favorable for their propagation.

OVIPOSITION.

During the season of 1909 oviposition was not observed until March 10, and by March 15 any number of individuals could be seen placing their eggs. A few larvæ, however, were collected from almond trees on February 26, indicating that earlier eggs had been placed. The period of maximum oviposition begins about March 15, and almost all individuals will be found placing eggs after this date for a period of about four weeks. Ovipositing continues early and late during the day and in all conditions of weather.

THE EGG.

The egg (fig. 14), a white, bean-shaped body, is always embedded in the tender tissue of the stem, leaf, or in small fruits, and is thus protected. After about four days the larva hatches and pushes out through the incision immediately above it.

THE LARVA.

The thrips larva (fig. 15) is white, with red eyes; it moves about slowly and does not jump, and, being without wings, it can not fly. It does not spin a web, but seeks a sheltered place between rolled or folded leaves or in blossoms, or it lies close along the veins on some of the larger leaves. It reaches full growth after two or three weeks, drops to the ground, and penetrates into it for several inches, where it incloses itself in a tiny cell and here remains during all the rest of the year.

Larvæ do not walk down the larger branches or tree trunks to get to the ground, but drop down or are carried within the old falling calices, or are more usually thrown down by winds or rains. It has been observed that a very large percentage of the thrips which are thus thrown from the tree are not fully grown. Only those which are mature are able to penetrate the ground and form their cells; the others die. Larvæ are scattered everywhere under the trees, and if the trees are large and have intermingling branches the thrips are distributed over nearly the whole surface of the soil.

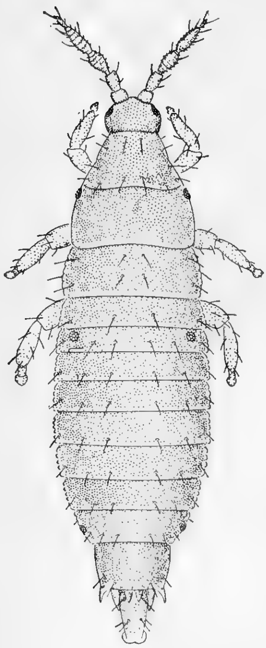


FIG. 15.—The pear thrips: Larva. Much enlarged. (Author's illustration.)

The period during which larvæ are entering the ground begins about April 1, and is at its maximum from about April 10 to 30, practically all thrips having entered by May 15. This period of entering the ground by larvæ in Contra Costa County corresponds very closely to the San Jose record as given above. It may be a few days earlier in the warmer sections at Suisun, in the Vaca Valley, and along the Sacramento River.

Larvæ penetrate the loose top soil and usually remain in the 3 or 4 inches of harder ground immediately below the surface. They penetrate to a much greater depth where the soil is loose, owing to shallow spring cultivation, than where it is firmer. If the thrips are disturbed during their first few weeks in the ground—for example, by cultivation—and if not killed, they immediately go deeper and make new cells. The larvæ remain in a dormant condition, in which no food is taken, and do not move from their cells, unless disturbed, until the fall of the year, when they change to pupæ and their wings begin to develop.

The depth to which these insects penetrate in well-cultivated or-orchards may be noted in the following tables. In the establishment of these records, blocks of soil 6 by 6 inches square by 20 inches deep were removed from underneath prune and pear trees, brought to the laboratory, and examined in layers, inch by inch, the thrips in each layer being counted. The figures in each case represent the total of all of the samples from each orchard—6 from the Bogen orchard, 10 from the Landon, and 4 each from the Hume and Sorosis orchards. The percentages represent what proportion of the thrips are in the soil above the mentioned depth after which the percentage figures stand. The loose top soil of about 4 inches contained no thrips.

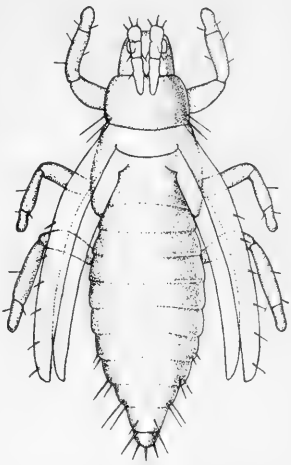


FIG. 16.—The pear thrips: Nymph or pupa. Much enlarged. (Author's illustration.)

TABLE II.—*Proportion of larvæ of pear thrips in ground at different depths; records from four orchards in the Santa Clara Valley, California.*

No. of layer.	Depth.	Depth of larvæ in soil. Bogen orchard (6 samples). No. of thrips.	Bogen orchard Per cent.	Landon orchard (10 samples). No. of thrips.	Landon orchard Per cent.	Hume orchard (4 samples). No. of thrips.	Hume orchard Per cent.	Sorosis orchard (4 samples). No. of thrips.	Sorosis orchard Per cent.
	Inches.								
5	4 to 5	3	....	249	....	188	....	1	....
6	5 to 6	29	7.75	518	25	277	74	14	12
7	6 to 7	39	17.75	829	54	92	88	55	55
8	7 to 8	45	29	501	71	38	94	25	75
9	8 to 9	71	46.75	305	81	14	95	6	80
10	9 to 10	58	61.25	168	87	7	....	8	....
11	10 to 11	41	71.5	172	....	3	....	9	....
12	11 to 12	26	78	87	....	2	....	6	....
13	12 to 13	25	84	21	....	2	....	1	....
14	13 to 14	17	....	76	....	3	....	0	....
15	14 to 15	12	....	33	....	1	....	1	....
16	15 to 16	4	....	0	....	0	....	0	....
Total number of larvæ.		370	....	2,959	....	627	....	126	....
Average number larvæ per surface sq. foot...		266	....	1,183	....	627	....	126	....

THE PUPA.

The period of pupation begins in September and reaches its maximum during October, November, and December. The insect is at this time forming its new legs, antennæ, and wings, each appendage developing within its own little sac and hanging free at the side of the body (fig. 16). A few prematurely forming pupæ have been collected during midsummer, but it is not probable that these live through the year. They do not mature to form a second brood.

THE ADULT.

Adult thrips (fig. 17) are common in the ground in December and January, but all seem to await the proper time in February before they come out. If they are prematurely broken out from their cells during December or January they are active and can fly, but they never seem to leave the ground at this time of their own accord. The transformation from larva to pupa and to the adult is a slow and gradual one and occupies several months.

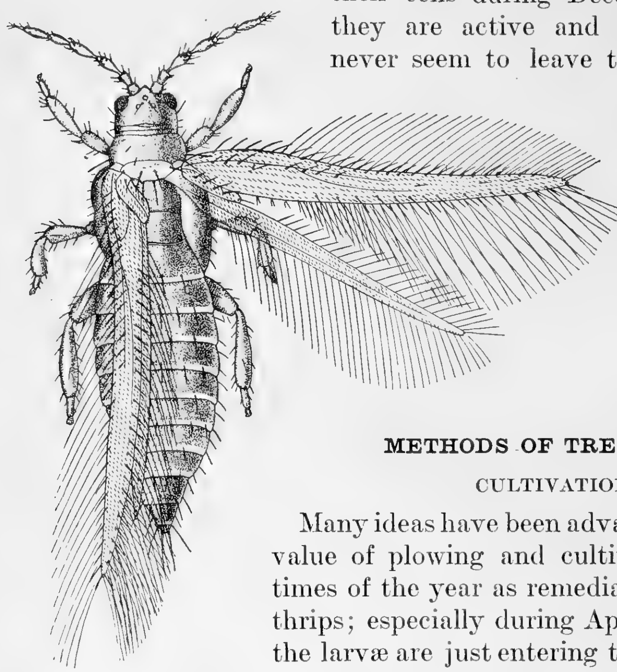


Fig. 17.—The pear thrips: Adult. Much enlarged. (Author's illustration.)

METHODS OF TREATMENT.

CULTIVATION.

Many ideas have been advanced regarding the value of plowing and cultivating at different times of the year as remedial measures against thrips; especially during April and May, when the larvæ are just entering the ground; in May, June, and July, after they are all in; in the fall and early winter, to destroy pupæ; and during February and March, when adults are coming out. It has now been clearly demonstrated that much benefit can be derived in checking the thrips by plowing and otherwise cultivating the ground, if this is done at a proper time and with care.

Thrips larvæ penetrate until they can find a protected place where no light enters. This may be within 2 or 3 inches of the surface, in ground along roadways which is not cultivated and which may be partly covered with grass. They usually rest in the 3 or 4 inches of ground immediately below the loose top soil in regularly cultivated land, and since they are within 8 or 9 inches of the surface, they are thus largely within the reach of the plow. If, from previous improper cultivation, the ground is full of cracks and cavities from decayed weed stems or roots, or is full of wormholes, the larvæ come into these and may then penetrate many inches.

Cultivation during April and May, when the thrips larvæ are entering the ground, will kill a few, but it also disturbs and agitates the others, which then go deeper. Continuous cultivation in June and July, which, however, is not always practicable, would also have the same effect. It should be remembered that these insects are so small that they can easily remain inside of very small clods and be turned over and over again by cultivation without receiving any injury.

The thrips are passing through their pupal development in the late fall and early winter, and they are then more susceptible to mechanical injury than at any other time. They are only slightly active, and can not build other cells if once they are forced from the old ones. Their new legs, antennæ, and wings are sheathed in long, delicate sacs, any one of which may easily be broken or deformed by the least disturbance.

Several experiments with fall and winter plowing for thrips were carried out in the fall of 1908, and the following records show what results have been obtained in two of these orchards, where special attention was given to securing data. Areas of 20 and 70 acres, respectively, were plowed and harrowed, and all of the first, with 20 acres of the second, was cross plowed. This plowing was done mostly during December, a lack of early rains having hindered from doing the work sooner. In each case several samples of soil, 17 by 17 inches square by 20 inches deep, were removed from the orchards, both before and after treatment, brought to the laboratory yard, and embedded to their natural depth in the ground. The cages remained open until a time when the adult thrips began to come out. They were then covered over, and thereafter a daily record of the emerging insects was made for each. The blocks of soil were selected from near-by trees and under like conditions, to insure as far as possible a uniform number of thrips in each.

Cages I, II, III, and IV from the Landon orchard were taken from land which had been plowed and cross plowed in November and December, and cages V and VI, from the same orchard, were taken from under trees where no winter plowing had been done. Cages VII and VIII, from the Hume orchard, were taken from land which was plowed and cross plowed, and cages IX and X from untreated soil.

TABLE III.—*Experiments with fall and winter plowing for the pear thrips in two orchards in the Santa Clara Valley, California.*

LANDON ORCHARD.

	Plowed and cross plowed.				Not treated.	
	Cage I.	Cage II.	Cage III.	Cage IV.	Cage V.	Cage VI.
Total number of thrips	475	389	607	115	1,175	1,474
Total number of thrips per square foot of surface	237	194	303	57	587	734

Average number of thrips per cage:	
Cages I, II, III, and IV	396
Cages V and VI	1,324
Average number of thrips per square foot of surface in each cage:	
Treated	198
Untreated	662
Percentage living in treated areas as against the numbers of thrips in untreated ground	30
Approximate percentage killed	70

TABLE III.—*Experiments with fall and winter plowing for the pear thrips in two orchards in the Santa Clara Valley, California*—Continued.

HUME ORCHARD.

	Plowed and cross plowed.		Not treated.	
	Cage VII.	Cage VIII.	Cage IX.	Cage X.
Total number of thrips	421	643	2,185	1,771
Total number of thrips per square foot of surface	210	321	1,092	885

Average number of thrips per cage:	
Cages VII and VIII	265
Cages IX and X	988
Average number of thrips per square foot of surface in each cage:	
Treated	133
Untreated	494
Percentage living in treated areas as against the numbers of thrips in untreated ground	27
Approximate percentage killed	73

Bearing in mind that the larvæ penetrate into the ground quickly after they leave the trees; that they remain usually below the loose top soil, going deeper if disturbed, and also that they are most susceptible to injury in the pupal stage, cultivating and plowing should be so arranged as to take best advantage of their habits, to encourage their locating near the surface, planning at the same time to reach them by late fall and early winter plowing.

The principle of fall plowing is to use a moldboard or disk plow, and by turning the land over to bring the thrips which rest in the lower strata of ground up to the surface. The land should then be thoroughly harrowed or worked over with a disk cultivator. With the present methods of plowing, a strip of 2 feet or more of undisturbed ground is usually left in the tree row. It is necessary also to plow to a less depth close under the trees than in the middle of the rows. The land should therefore be plowed and cross plowed, to insure breaking up all of the ground to a uniform depth, and harrowed after each plowing, to make the treatment thorough.

The Landon orchard was uniformly plowed to a depth of about 9 inches. It will be seen by referring to Table II that 81 per cent of all the thrips were above this depth and were therefore disturbed. Table III shows that there were 70 per cent less live thrips in ground which had been plowed and cultivated than in that which had received no winter treatment. These thrips, about 89 per cent of all which were disturbed, must therefore have been killed by the cultivating.

The Hume orchard was plowed uniformly to a depth of about 7 inches. Table II shows that 88 per cent of the thrips were between the surface and this depth, and Table III shows that about 73 per cent of the total number of thrips in this orchard were killed by cultivation.

Plowing during February and March, when adult thrips are coming out of the ground, is not practicable because of the usually heavy rainfall at this time, and because the ground breaks up into large instead of small clods, for which reason only a few thrips are killed. Then, too, plowing at this time seems to let the thrips out all at once, thus increasing rather than reducing their injury. Several orchards that have been kept under constant observation, which were plowed during February and early March, were very much more seriously injured than orchards of the same variety of fruit immediately adjoining which were not plowed at this time.

The benefits of plowing and cross plowing have been so evident in every one of the several orchards treated that during the spring one could tell almost to a row, by the healthful condition of the trees, where the plowing began and where it ceased.

A careful examination of the soil under prune trees, after plowing had been accomplished, showed that almost no thrips were present until a depth was reached where the plows had not cut. Below this point the usual numbers of thrips were found.

SPRAYING.

Spraying for thrips has proved wonderfully successful wherever proper sprays have been used and the work done with care and thoroughness, while indifferent and careless work or improper sprays are absolutely ineffective. The thrips must first of all be reached. This necessitates high pressure—125 to 180 pounds—and a rather coarse, penetrating spray. It is necessary also that the spray be directed downward into the buds, and not thrown at them from below or from the sides. It should be remembered that spraying is done, not to drive the insects away or to protect the tree from any possible future attack, but to kill those insects which are actually present on the trees. It may not be possible to reach all of the thrips which are concealed in the buds even with most careful spraying, but a very large percentage of them can be killed. Spraying into partly opened buds and blossoms theoretically seems impossible, but is found entirely practicable when a coarse, forceful spray is thrown down directly against the tips. A tower platform should be built over the spray wagon so that the tops of large trees can be properly sprayed.

Almost all of the standard spray formulas have been thoroughly tested, and all except two have been eliminated. The bodies of the thrips, both adults and larvæ, are decidedly oily and strongly resistant to all sprays which do not readily assimilate the oil. For example, the lime-sulphur solution, which is very caustic, may be thrown onto the thrips, and it will merely gather in globules on their bodies and not penetrate to kill them. Both larvæ and adults have been observed to actually float around in the ordinary soap and lime-sulphur sprays with no apparent inconvenience. Dry sprays are also absolutely ineffective. Emulsions of oil combined with crude carbolic acid or crude creosote are extremely penetrating, in reality killing almost every thrips that they touch, even when applied in a very weak form; but these combinations are just as violently injurious to blossoms and leaves as to thrips, consequently they can not be considered. Poisonous sprays are ineffective because the thrips feed from the inner parts of the plant and not from the outer layers, where the poison would be placed.

Black-leaf tobacco extract diluted to proportions of 1 part extract to 50 of water has been very successful, but this spray seems to demand a somewhat heavier and more penetrating liquid than water alone as a carrying agent. The distillate oil emulsion in 6 per cent dilution is almost as deadly as the black-leaf extract, but there will follow some injury from the spray unless conditions are altogether favorable. The oil spray has the advantage of being heavier, of being forced more easily into the buds, and of penetrating the oily coating offered by the thrips. This emulsion, however, reduced to a 1½ or 2 per cent solution, can be applied with safety to all trees, and when combined with black-leaf extract, diluted at the rate of 1 part of extract to 60 or 70 parts of water, furnishes a spray having all the required carrying, penetrating, and killing qualities desired. This is the spray which is now recommended. It can be applied with safety to opening buds, but should not be used on trees in full bloom. Blossom petals are more sensitive to injury from spraying than any other parts of a tree; but, since they soon fall, the damage, although noticeable, is not often serious. This spray can be applied to trees immediately after the blossoms have fallen, and later to the foliage for adults and larvæ.

The first application should properly be made when the thrips are coming from the ground in large numbers and before the cluster buds are too far advanced. (See Pl. IV, showing stage of development of buds when first application should be made.) This period for the San Jose district of California is early in March, but it differs, of course, for the several varieties of fruits, as stated on page 54. Where the thrips are very numerous it may be necessary to immediately follow this first application with a second. Another application can be made immediately after the blossom petals fall, to kill the remaining adults, but more especially to kill the larvæ. The adults should by all means be attacked first. The spraying for larvæ is merely to alleviate the minor injury of scabbing on fruits, and to protect the trees for the following year by killing the larvæ before they get into the ground.

An effort should be made to kill all adults in an orchard before March 15, when practically all thrips are out of the ground and when oviposition begins.

The black-leaf tobacco extract may be purchased from local agents. The distillate oil emulsion can also be purchased from local dealers in spraying supplies, but is prepared after the following formula:

Hot water	gallons	12
Whale-oil or fish-oil soap	pounds	30
Distillate oil (28° Baumé)	gallons	20

The soap is first dissolved in a kettle of boiling water and then removed to the spray tank, where the oil is added. This should be agitated violently and sprayed out under pressure of from 125 to 150 pounds into other barrels. This stock solution contains about 55 per cent of oil, and should be diluted at the rate of about 2 gallons of the emulsion to 48 gallons of water for a 2 per cent oil solution.

The secret of making a thoroughly good stock emulsion lies in having the soap and water boiling hot, in adding the oil to this solution, and under no circumstances in adding the soap and water to the oil, in thorough and violent agitation, and, finally, in passing it through the spray nozzles under high pressure. It has been found by repeated experiments that high pressure is the most important factor, and an emulsion passed once through the pumps and nozzles under pressure of from 150 to 160 pounds can not be improved by repeating this operation.

Fish-oil soap may be made as follows:

Water	gallons	6
Lye	pounds	2
Fish oil	gallons	1½

Place the water in a caldron, add the lye, and then the fish oil, and boil slowly for about two hours. This will make about 40 pounds of soap or about a 5-gallon mixture.

FERTILIZERS.

The numerous fertilizers and soil fumigants tested have proved ineffectual in killing thrips in the ground, even when applied in proportions far beyond what could be used in ordinary practice. It is evident, however, that most orchards need fertilizers to strengthen the buds and to insure a more regular setting of fruit. It has been demonstrated repeatedly with other crops that soil soon deteriorates unless there is a rotation of crops or unless fertilizers are added.

IRRIGATION.

Irrigating for thrips during any time of the year is entirely ineffectual. Their bodies are so strongly resistant to water that while in the ground it is not practicable to submerge them long enough to insure their destruction. Small areas containing thrips have been submerged as long as seventy-two hours, and when examined a few days later all thrips were alive and active.

SUMMARY.

The pear thrips has been found only in localities in the general region of San Francisco Bay. Its presence in other countries is not known.

The adults accomplish their feeding injury by rasping the tissues and sucking out the plant juices in the early buds and blossoms. Larvæ feed more especially on the larger leaves and on fruits. Adults cause the scabbing on pears, while larvæ produce the scabbing on prunes.

Adults emerge from the ground in late February and early March, just when most trees are spreading their buds and opening into bloom. Eggs are placed mostly in the blossom and fruit stems and in leaf petioles. The larvæ hatching therefrom feed for two or three weeks, then drop to the ground, where they form a tiny protecting cell within which they remain during the rest of the year. The pupal changes take place within this cell in the ground during October, November, and December.

To gain complete control of the pear thrips, both plowing and spraying should be adopted as remedial. Land should be plowed as soon as possible after the early rains in October, November, and December, to a depth of from 7 to 10 inches, harrowed or disked, and then cross plowed, the second plowing to be followed also by harrowing. The pupæ are by this means broken from their protecting cells and most of them either injured or killed.

A combination spray of black-leaf tobacco extract in the proportion of 1 part of extract to 60 parts of water and 2 per cent distillate oil emulsion, or a spray of black-leaf extract alone, should be used against the adults during early March, just when the cluster buds begin to open, and against the larvæ in April, after the blossom petals fall. The thrips must be killed by contact insecticides, and not by internal poisons.

Fertilizers and irrigation do not kill the thrips in the ground. They act against them only indirectly, by placing the soil in better condition for cultivation and by strengthening the trees.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part V.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

ON THE NUT-FEEDING HABITS OF THE CODLING MOTH.

BY

S. W. FOSTER,

Engaged in Deciduous Fruit Insect Investigations.

ISSUED SEPTEMBER 20, 1910.

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ON THE NUT-FEEDING HABITS OF THE CODLING MOTH.

By S. W. Foster,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

The codling moth (*Carpocapsa pomonella* L.) has, up to the present time, been considered as a serious enemy only to pome fruits. It has, however, frequently been found in peaches and plums. There are several European records of walnut infestation by this species, but these reports were carefully sifted by Dr. L. O. Howard in 1887[a] and found to lack sufficient evidence to definitely prove that the codling moth ever feeds either upon nuts or oak galls. C. B. Simpson[b] records that Adkin, in 1895 and in 1896, exhibited specimens and gave details as to the rearing of this insect from chestnuts. In March, 1908, at Siloam Springs, Ark., the writer found a full-grown larva of this species with partially made cocoon inside a hickory nut, but as there were no signs of feeding on the kernel it is probable that the larva had gone in only for the purpose of hibernation and as a safe place for pupating.

NOTICE OF WALNUT INFESTATION.

On October 2, 1909, while visiting the ranch of Mr. George Whitman, near Concord, Cal., the owner mentioned to the writer that worms closely resembling the larvæ of the codling moth were doing serious injury to the walnuts on one of his trees. A large tree near a pear-packing shed was closely examined and found to have over 50 per cent of the nuts infested by larvæ of the codling moth. Larvæ in all stages from a few days old to full grown were found. Eggshells also were found on the outside of the hull of the nuts and on the leaves, indicating that the eggs had been placed by the moth on fruit and foliage promiscuously, as is customary in the case of apple and pear.

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[a] Rept. Commissioner of Agriculture for 1887, pp. 92–94, 1888.

[b] Bul. 41, Bur. Ent., U. S. Dept. Agr., p. 19, 1903.

NATURE OF INJURY.

The larvæ upon hatching soon bore into the fleshy hull covering the walnut proper. Some individual larvæ one-fourth grown were found feeding in this hull, some burrowing around through the fleshy part, and others tunneling back and forth on the inner surface next to the walnut shell, producing many little narrow furrows along this inner surface. The majority of the larvæ, however, go at once into the nut, entering always through the fibrous tissue connecting the halves of the shell at the base or the stem end. The larvæ may bore into the lobes of the kernel or feed on its surface. Some eat over a large portion next to the shell, some follow along the central area, while others may spend all the time near the entrance, eating away a larger portion of the kernel at this place. In any case the entire kernel is rendered rancid and unsuited for human consumption. Plate VII, figure 1, shows characteristic injury to the walnuts and Plate VII, figure 2, a larva at work in the kernel, the latter twice enlarged.

EXTENT OF INFESTATION.

Extended search throughout the central part of Contra Costa County, Cal., showed the infestation to be general, but light, except where trees were near packing sheds, drying grounds, or adjacent to a badly infested pear orchard. Many trees were found in such localities showing from 5 to 25 per cent of the nuts infested. During the winter of 1909–10 small quantities of walnuts were frequently bought in the local markets and twice from stands in San Francisco from which codling moth larvæ were secured and which showed the characteristic injury to the kernel. The writer has also had the same experience with walnuts served on hotel and dining-car tables. Mr. E. J. Hoddy, of the Bureau of Entomology, has frequently, during the past winter, brought in walnuts from various parts of the county showing the injury and presence of these larvæ.

VARIETIES ATTACKED.

All of the soft-shelled French varieties of walnuts are subject to infestation, and in fact any of the soft-shelled sorts having a fibrous tissue connecting the halves of the shell at base. Moths were reared the past season from the Mayette, Concord, Franquette, and Parisienne varieties.

SEASONAL HISTORY OF THE CODLING MOTH ON WALNUTS.

So far all observations indicate that only the later broods of larvæ attack the walnuts. No walnuts could be found showing early injury, that is, before the shell hardened. Assuming that the larval life in walnuts is the same in length as in apples and pears, the earliest date of infestation would be late August or early September. The Bart-

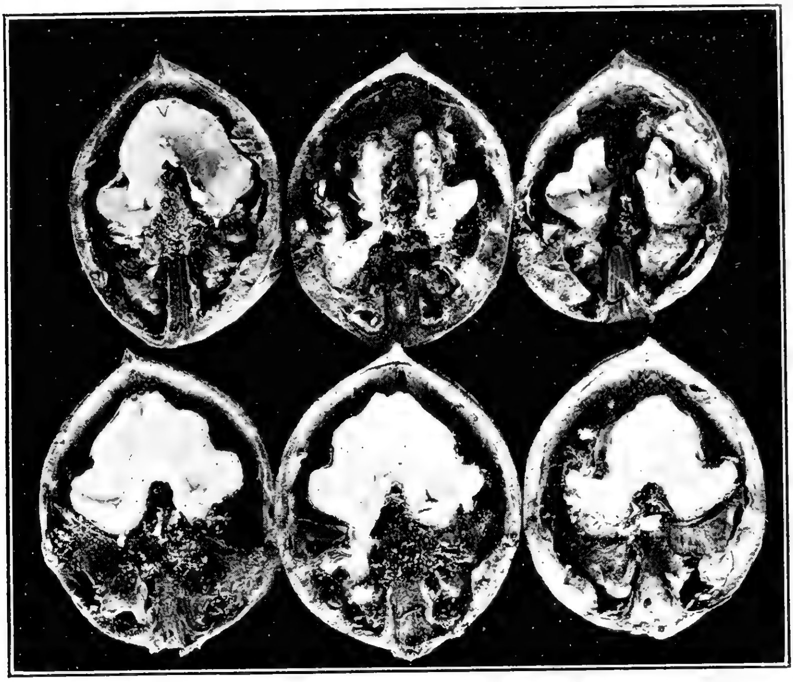

FIG. 1.—CONCORD VARIETY OF ENGLISH WALNUT, SHOWING CHARACTER OF INJURY BY LARVÆ OF CODLING MOTH. (ORIGINAL.)

FIG. 2.—CONCORD VARIETY OF ENGLISH WALNUT, ABOUT TWICE NATURAL SIZE, SHOWING LARVA AT WORK. (ORIGINAL.)

CODLING MOTH INJURY TO ENGLISH WALNUTS.

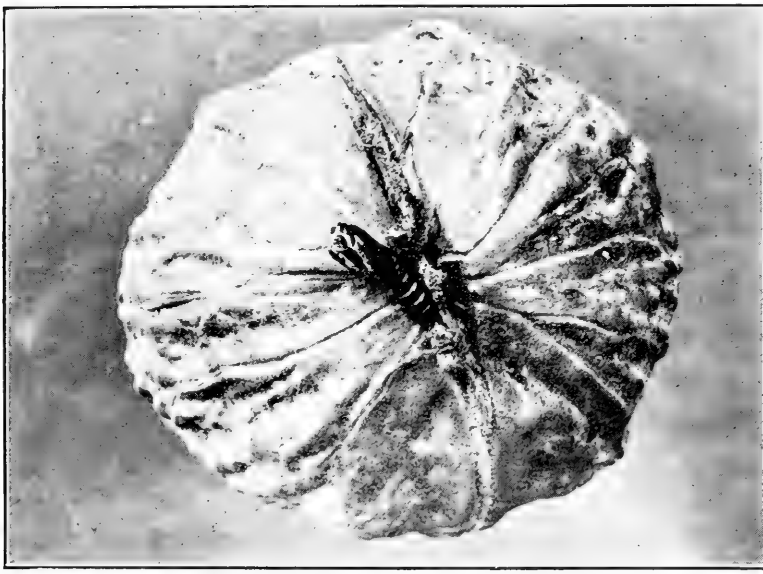

FIG. 1.—CONCORD VARIETY OF ENGLISH WALNUT, SHOWING FIBROUS TISSUE CONNECTING THE HALVES, AND EMPTY PUPAL SKIN. (ORIGINAL.)

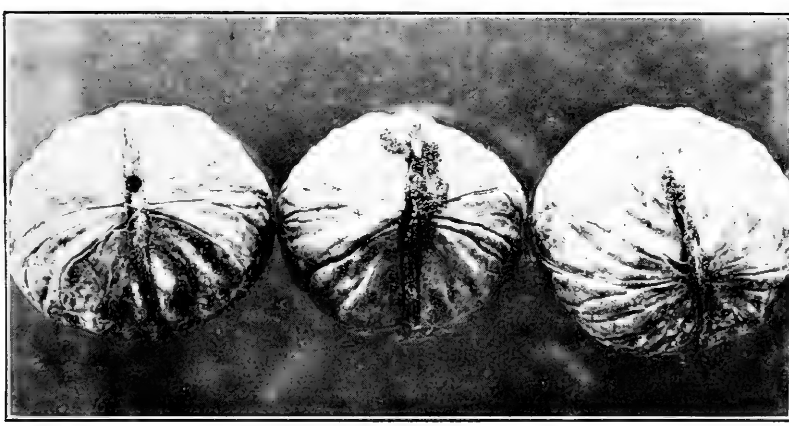

FIG. 2.—CONCORD VARIETY OF ENGLISH WALNUT, SHOWING ENTRANCE AND EXIT HOLES OF LARVA. (ORIGINAL.)

CODLING MOTH INJURY TO ENGLISH WALNUTS.

lett pear crop around Concord, Cal., is picked prior to this time and before all the second-brood moths have developed. It is entirely probable that these late-appearing individuals seek the walnut as the only remaining plant suitable for oviposition. Thorough search during May and June, 1910, failed to show the presence of any larvæ on trees that were badly infested last season.

Life of larvæ in walnuts.—In spite of the extreme bitterness of the fleshy hull, some larvæ thrive well there for a time before entering the kernel, as several specimens of healthy, active larvæ one-fourth to one-half grown were found in the hull. However, in all cases under observation the larvæ left the hull and entered the kernel before reaching maturity. The majority of the larvæ burrow directly through the fibrous tissue connecting the halves of the shell. Some larvæ are saved the necessity of burrowing through the hull, as this, during the period of infestation, is ripening on many of the early nuts, and on account of the parting of the lobes the small larva has only to eat its way through the thin fibrous connection. No case was noted where the larva entered through the shell.

Time required for development.—No individual records were kept, but all observations show that the larva develops as rapidly on the meat of the walnut as it does in apples at this season of the year. Some larvæ less than a week old, collected in walnuts October 5, reached their full development and were spinning cocoons by the middle of November. Others, however, continued to do more or less feeding on the kernel and did not spin cocoons until January.

Hibernation.—From 1 gallon of infested walnuts kept at the laboratory perhaps one-fourth of the larvæ cocooned and pupated inside the shell. Others, leaving the walnuts at the same place where they entered—that is, through the fibrous tissue connecting the halves of the shell—pupated in bits of paper and rags kept in the jars. Before pupating in the walnuts, the larva prepares an opening through the fibrous tissue sufficient for the exit of the moth and spins its cocoon immediately adjoining this opening. Upon the emergence of the moth the shed pupal skin is left outside on the end of the walnut, as is shown in Plate VIII, figure 1. All larvæ under observation pupated between February 20 and April 10.

Adults.—Moths emerged in numbers from the above material during April and May, 1910, comparing closely with the emergence record of moths from a quantity of overwintering larvæ taken from bands on apple trees the previous season.

Identification.—Numerous adults emerging from this material were submitted to Mr. August Busck, of the Bureau of Entomology, for identification. Mr. Busck has definitely determined these as *Carpocapsa pomonella* L.; he states that the European *Carpocapsa putaminana* Staudinger, recorded as feeding on walnuts in Europe, is now regarded as a variety of *pomonella.*

CONTROL.

As many of the larvæ eat their way through the fleshy hull covering of the walnut, it is probable that a thorough spraying with arsenate of lead in the month of August would greatly reduce the infestation. This treatment would apparently be as effective in destroying larvæ from eggs placed promiscuously over the foliage and nuts as in the case of the apple. From the fact that many of the larvæ gain entrance to the walnut after the hull has parted at the tip, the poison would, of course, not be effective against these. The infestation can, no doubt, be greatly reduced by maintaining the packing shed and drying grounds some distance from the walnut grove.

It is the practice of many pear growers to save all windfalls in the orchard and culls from the packing shed. These pears are either stored in large trays, stacked in the shade, or else the pears are covered with straw in layers on the ground. As a rule, the culls from the packing ground are nearly all infested with immature larvæ of the codling moth, which reach their full development and produce moths during the ripening period of the walnuts. This, in most cases, is the source of infestation of walnut groves found to be most seriously troubled with the codling moth.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part VI.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIFE HISTORY OF THE CODLING MOTH IN NORTHWESTERN PENNSYLVANIA.

BY

A. G. HAMMAR,

Engaged in Deciduous Fruit Insect Investigations

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIFE HISTORY OF THE CODLING MOTH IN NORTHWESTERN PENNSYLVANIA.

By A. G. Hammar,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

In 1907 the section of deciduous fruit insect investigations of the Bureau of Entomology established at North East, Pa., a temporary field station, for the investigation of certain orchard and vineyard pests. One of these, the codling moth (*Carpocapsa pomonella* L.), has been studied for the three consecutive years of 1907, 1908, and 1909. The rearing work during the first two seasons covered only the more important features in the development of the insect, while in 1909 efforts were made to rear the insect throughout the seasons and to determine the time and relative occurrence of the various stages of the two broods.

In 1907 the work was carried out by Mr. P. R. Jones of this Bureau, and in 1908 and 1909 by the writer, who during the last season was assisted by Mr. Edwin Selkregg, of North East, Pa. Mr. Fred Johnson, of this Bureau, has for the three seasons contributed to this work numerous field observations. All of these studies have been made under the direction of Mr. A. L. Quaintance, in charge of deciduous fruit insect investigations.

In the presentation of the life-history studies the separate stages of the two generations are first considered in detail as observed in 1909. Later are described certain fluctuations, found in regard to the time of emergence of moths, the time of maturity of larvæ of the two broods, and also a comparison of relative occurrence of larvæ of the two broods for the three seasons under consideration.

The term "brood" is here used in speaking of individuals of one generation of any stage, as egg, larva, or pupa. A generation naturally includes all the stages of the life cycle, and is considered to begin with the egg stage and to terminate with the moth or imago stage of the same generation.

SEASONAL-HISTORY STUDIES OF 1909.

SOURCE OF REARING MATERIAL.

The main portion of the rearing material used in the spring of 1909 was collected during the previous summer and fall from banded apple trees; the rest—a small fraction—constituted reared specimens from experiments of the previous year. The larvæ intended for pupal records were allowed to make their cocoons between narrow strips of wood (fig. 18), where their transformation could be readily observed without greatly altering their conditions, while those for emergence records of the moths cocooned in masses of old bark of apple trees. During the winter the material was kept in a medium-sized glass jar, covered with thin cloth, and was thus left undisturbed in an open shelter (see Plate IX) until the following spring.

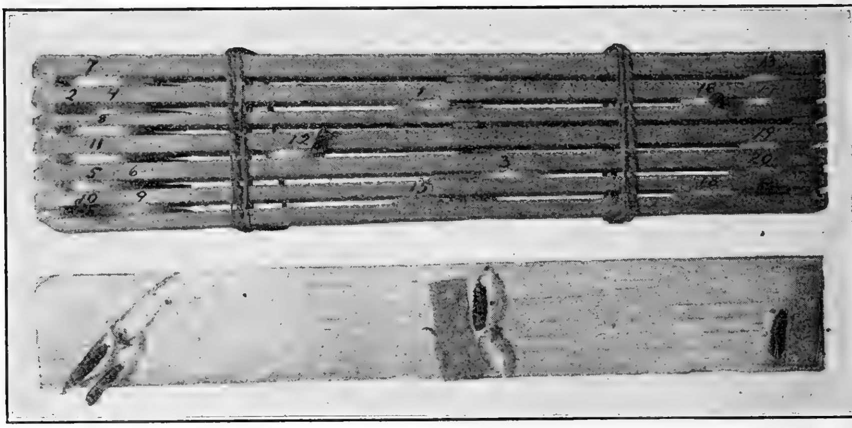

FIG. 18.—Device consisting of strips of wood held together by rubber bands used in obtaining pupal records of the codling moth (*Carpocapsa pomonella*). Reduced. (Original.)

The rearing material for the following emergence of moths, or first-brood moths, was mainly from that used in taking the band records of 1909, and, to a small extent, from reared specimens. There is a special value in the use of band-collected larvæ in the rearing of the codling moth, in that these have up to the time of transforming developed normally in the field and the resulting adults show thus both the normal time of emergence and the relative occurrence in the field.

OVERWINTERING LARVÆ.

The overwintering larvæ of the codling moth in the vicinity of North East, Pa., are partly of the first and partly of the second broods. As is more fully considered on page 84, a portion of the first-brood larvæ, unlike the rest, hibernate—as do normally all larvæ of the second brood—and complete their life cycle the following spring.

PORTION OF OUTDOOR SHELTER USED IN REARING THE CODLING MOTH IN 1909, AT NORTH EAST, PA. (ORIGINAL.)

Unless reared, the larvæ of the two broods can not be separated and are simply referred to as overwintering larvæ. Similarly the resulting pupæ and moths in the spring originate from the two separate broods of the previous year's larvæ, and these are spoken of as "spring-brood pupæ" and "spring-brood moths."

SPRING BROOD OF PUPÆ.

Time of pupation.—In the rearing cages the first observed pupation took place May 24. Considering, however, the time of the earliest record for the emergence of moths, and the duration of the pupal stage, which at that time of the season lasted 24 days, it is probable that pupation must have begun as early as May 20. The last larvæ of the wintering broods pupated June 25. The pupation period thus covered a length of time of over one month (fig. 22). Since the last moth of the spring brood emerged July 17, pupæ were in evidence from May 20 to July 17.

Length of spring pupal stage.—In cage experiments, records were obtained of the duration of the pupal stage for 50 individuals. (See Table I.)

TABLE I.—*Length of pupal periods in spring brood from wintering larvæ, collected during 1908, on banded trees.*

No.	Date of—		Days.	No.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.	
1	May 24	June 17	24	28	May 29	June 21	23
2	May 25	June 16	22	29	May 30	June 22	23
3	...do.....	June 19	25	30	...do.....	June 17	18
4	...do.....	June 28	34	31	May 31	June 22	22
5	May 26	June 17	22	32	...do.....	...do.....	22
6	...do.....	June 20	25	33	...do.....	...do.....	22
7	May 27	...do.....	24	34	...do.....	June 21	21
8	...do.....	...do.....	24	35	...do.....	...do.....	21
9	...do.....	...do.....	24	36	June 1	June 23	22
10	...do.....	June 27	31	37	...do.....	...do.....	22
11	...do.....	June 20	24	38	...do.....	...do.....	22
12	...do.....	...do.....	24	39	...do.....	...do.....	22
13	...do.....	...do.....	24	40	June 2	...do.....	21
14	...do.....	June 14	18	41	...do.....	...do.....	21
15	...do.....	June 20	24	42	...do.....	...do.....	21
16	...do.....	...do.....	24	43	...do.....	...do.....	21
17	...do.....	...do.....	24	44	June 17	July 2	15
18	...do.....	June 14	18	45	...do.....	July 3	16
19	May 28	June 19	22	46	...do.....	July 4	17
20	...do.....	June 20	23	47	June 18	...do.....	16
21	...do.....	...do.....	23	48	June 20	....	......
22	...do.....	June 21	24	49	...do.....	....	......
23	...do.....	June 20	23	50	...do.....	....	......
24	...do.....	June 16	19	51	June 21	July 6	15
25	...do.....	June 21	24	52	June 23	July 8	15
26	May 29	...do.....	23	53	June 25	....	......
27	...do.....	...do.....	23				
			639				438
Total			1,077				

The variations in the length of the pupal periods, as shown in Table II, extended from 15 to 30 days.

TABLE II.—*Spring brood of pupæ. Variations in the length of the pupal periods as recorded in Table I.*

Pupæ.	Days.	Pupæ.	Days.
3	15	10	22
2	16	7	23
1	17	12	24
3	18	2	25
1	19	1	31
6	21	1	34

The length of the stages were especially prolonged during the early part of the period of pupation and shortest toward the close of the period, due to a difference in the temperature. In Table III is given a summary of the observations recorded in Table I, showing an average pupal period of 22 days for the total number of observations.

TABLE III.—*Spring brood of pupæ. Summary of pupal periods of Table I.*

Observations.	Days.
Average	21.98
Maximum	34
Minimum	15

SPRING BROOD OF MOTHS.

Time of emergence of moths in the spring.—In figure 19 is shown graphically the time of emergence and the relative occurrence of moths of the spring brood. The records for these observations are given in Table IV.

TABLE IV.—*Emergence of spring moths, 1909, from wintering material collected on banded trees during 1908.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
June 12	1	June 21	31	June 30	13	July 9	4
June 13	....	June 22	23	July 1	25	July 10	2
June 14	5	June 23	50	July 2	15	July 11	1
June 15	3	June 24	40	July 3	3	July 14	2
June 16	6	June 25	50	July 4	5	July 17	1
June 17	13	June 26	33	July 5	10		
June 18	1	June 27	32	July 6	6		486
June 19	10	June 28	35	July 7	8		
June 20	24	June 29	30	July 8	4		

Indoors, moths were observed previous to June 12, but since these undoubtedly had wintered in the house their appearance does not represent normal conditions, as is believed to be the case with material which had been kept out of doors during the winter. The emergence reached its maximum on June 23 and 24, and on July 17 the last moth emerged.

Time of emergence of moths in the spring versus the time wintering larvæ leave the fruit the preceding year.—In Table V is given a detailed

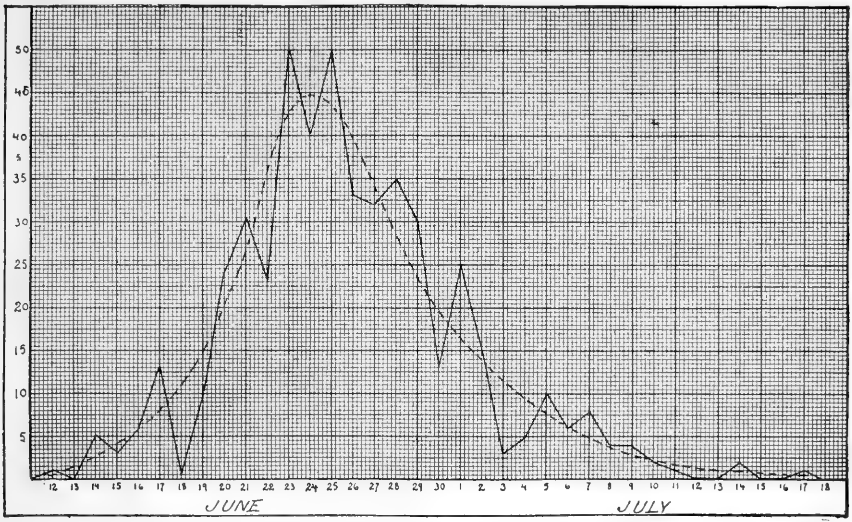

FIG. 19.—Emergence curve showing spring-brood moths in 1909, at North East, Pa. (Original.)

account of the band records of 1908, including the dates of collecting, which extend from July 18 to November 9, and the daily emergence records of moths in the spring of 1909 for the 17 separate band collections.

TABLE V.—*Emergence of moths in 1909, from band material collected during 1908. (The time the larvæ leave the fruit in the fall has no bearing upon the time of emergence of the moths the following spring.)*

Band records.		Records of emergence of moths, 1909.																															Number of moths issued, 1908.	Number of moths issued, 1909.
		June.																		July.														
No.	Date of collecting, 1908.	12.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	14.	17.		
1	July 18	....	....	....	....	....	....	....	....	....	1	....		....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	66	1
2	July 25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	69	1
3	Aug. 1	....	....	....	....	....	1	....	1	1	1	....	2	2	1	....	1	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....	87	13
4	Aug. 8	....	....	....	....	1	....	....	....	....	....	2	....	2	2	5	5	3	2	1	....	....	....	2	1	....	....	....	1	....	....	....	25	27
5	Aug. 14	....	....	....	....	....	....	....	....	4	3	3	6	3	3	1	1	1	1	3	1	....	....	1	....	....	1	....	....	1	....	....	4	33
6	Aug. 22	....	....	....	....	....	....	....	2	....	1	3	6	9	2	2	1	4	....	1	2	....	....	....	1	1	1	1	1	....	....	....	1	38
7	Aug. 29	....	....	....	....	....	....	....	....	....	....	1	....	2	2	1	4	....	....	....	1	1	....	....	....	1	....	....	....	....	1	....	....	14
8	Sept. 5	....	....	....	....	....	....	....	1	2	....	3	3	4	1	1	4	....	....	2	2	....	....	1	1	....	....	....	....	....	....	....	....	25
9	Sept. 12	....	....	1	2	2	....	1	6	3	1	5	....	2	2	6	1	2	2	2	2	....	1	....	1	....	1	....	....	....	....	....	....	43
10	Sept. 19	....	....	....	1	1	....	1	1	5	4	12	7	12	10	5	7	5	1	3	2	1	1	4	1	4	1	1	....	....	1	1	....	92
11	Sept. 27	....	1	1	1	1	....	2	4	5	3	8	4	5	3	4	5	2	....	5	....	....	1	....	1	....	....	....	....	....	....	....	....	56
12	Oct. 3	....	2	1	1	6	....	1	2	....	1	3	3	2	1	1	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	26
13	Oct. 12	....	2	....	....	2	....	....	4	3	5	1	....	3	3	1	3	9	2	5	5	1	1	....	....	....	....	....	....	....	....	....	....	50
14	Oct. 18	....	....	....	1	....	....	3	....	1	1	5	1	1	1	1	....	1	....	2	....	....	....	1	....	1	....	....	....	....	....	....	....	20
15	Oct. 26	1	....	....	....	....	....	....	....	2	1	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	7
16	Nov. 2	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
17	Nov. 9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
	Total..	1	5	3	6	13	1	8	22	27	22	46	33	47	31	28	33	30	12	24	15	3	4	9	6	7	4	3	2	1	2	1	252	449

The wintering larvæ belonged to both the first and the second broods. It will be seen by a glance at Table V that there was no marked difference in the time of emergence of moths from the first and the second brood larvæ. The division line between the two broods can be approximately determined as between August 29 and September 5, as shown in figure 27.

Time during the day when moths emerged.—When only one daily record of the emergence of the moths is taken, it is of importance to know the time when most moths emerge. A few observations, taken hourly, June 24, from 8.30 a. m. to 8.30 p. m. the same day, and continued, June 26, from 4.30 a. m. to 9.30 a. m., are recorded in Table VI.

TABLE VI.—*Spring brood of moths. Time of emergence during the day.*

Time of observation.		Emergence of moths.	Time of observation.		Emergence of moths.	Time of observation.		Emergence of moths.
Date.	Hour.		Date.	Hour.		Date.	Hour.	
June 24	8.30 a. m.	3	June 24	3.30 p. m.	....	June 26	4.30 a. m.	....
Do.	9.30 a. m.	....	Do.	4.30 p. m.	....	Do.	5.30 a. m.	....
Do.	10.30 a. m.	....	Do.	5.30 p. m.	....	Do.	6.30 a. m.	....
Do.	11.30 a. m.	1	Do.	6.30 p. m.	....	Do.	7.30 a. m.	1
Do.	12.30 p. m.	2	Do.	7.30 p. m.	....	Do.	8.30 a. m.	1
Do.	1.30 p. m.	1	Do.	8.30 p. m.	....	Do.	9.30 a. m.	....
Do.	2.30 p. m.	....	June 26	....	....			

Nine moths emerged during this period. The first emergence took place about 7.30 a. m. and the last about 1.30 p. m. During the afternoon, evening, and night no moths emerged. More observations on this habit of the moths are desirable in order to establish more accurately the time limits during the day when moths emerge. The above observations, however, suggest the general tendency. Possibly the varying temperature and moisture conditions of the day are influencing factors, because after the process of emerging the parts of the body, and particularly the wings, must expand quickly and assume a normal shape before hardening; in case of extreme dryness the wings may fail to expand.

Period of oviposition.—The moths in confinement frequently fail to oviposit, which is especially the case when a single pair or only a few individual moths are kept together. During the season of 1909 an abundance of eggs was obtained from moths confined in numbers of from 10 to 40 in medium-sized glass jars covered with thin cloth. Each jar contained a layer of moist sand; food, consisting of brown sugar and honey; and for oviposition, apples and apple twigs with foliage were supplied daily. As has been observed by other investigators, the eggs are laid during the evening and the night. In one instance a moth was observed in the act of ovipositing about 9 o'clock in the morning. The eggs were placed in abundance on the apples, the branches, and the foliage, and even on the bottom and on the sides of the jar. The apples and foliage were daily removed and replaced by fresh material, and to avoid infestation from hatching eggs, which had been placed on the sides and bottom of the jars, it became necessary to transfer the moths twice a week into new jars, the old ones being thoroughly cleaned before being put to further use.

In Table VII have been recorded the results from observations on oviposition in 12 rearing jars by moths of a given age. In no instance did oviposition take place until 2 days after the emergence of the moths, and on an average the eggs were first laid during the fourth day after emergence.

TABLE VII.—*Oviposition periods of spring-brood moths in rearing cages.*

Cage No.	Number of moths.	Date of— Emergence of moths.	First oviposition.	Last oviposition.	Days— Before oviposition.	Length of oviposition.	Between emergence and last oviposition.
1	7	June 16	June 23	June 25	7	3	9
2	10	June 17	June 27	June 29	10	3	12
3	10	June 19	June 24	June 24	5	1	5
4	17	June 20	June 23	June 30	3	8	10
5	11	June 21	June 24	June 29	3	6	8
6	10	June 22	June 25	July 1	3	7	9
7	39	June 23	...do.....	July 6	2	12	13
8	18	June 24	June 27	July 5	3	9	11
9	37	June 25	...do.....	July 7	2	11	12
10	23	June 29	July 7	July 15	8	9	16
11	15	July 1	July 5	...do.....	4	11	14
12	4	July 7	July 12	July 21	5	10	14
	201				55	90	133

The length of oviposition for each jar varied from 1 to 11 days, with an average of 7 days for the entire number of rearing jars. In one instance oviposition took place the sixteenth day after the date of emergence of the moths. On an average, however, oviposition extended to 11 days after emergence.

TABLE VIII.—*Oviposition periods of spring-brood moths. Summary of Table VII.*

Observations.	Days before oviposition.	Days of oviposition.	Days between emergence and last oviposition.
Average....................	4.6	7.5	11.08
Maximum..................	10	12	16
Minimum..................	2	1	5

In view of the abundance of eggs deposited and the manner in which they were laid, it was impossible to determine the number for a given moth. In the field the relative abundance of eggs during the season must be approximately in proportion to the occurrence of moths (fig. 19). In the rearing jars eggs were obtained from June 23 to July 15. Considering, however, the above observations on oviposition and the time of emergence of the first moths, it can closely and with some degree of accuracy be estimated that eggs were laid in the field from about June 17 to about July 22.

Length of life of the moth.—Records were kept relative to the length of life of the moths which were confined in jars for oviposition. The results of these observations are given in Table IX, with a summary in Tables X and XI showing the extent of variation in the length of life of 161 moths.

TABLE IX.—*Length of life of moths of the spring brood in rearing cages.*

Number of moths.	Date of— Emergence.	Date of— Death.	Days.	Number of moths.	Date of— Emergence.	Date of— Death.	Days.
6	June 21	July 2	11	1	June 25	July 12	17
3	...do.....	July 4	13	1	...do.....	July 14	19
2	...do.....	July 7	16	5	June 29	July 10	11
6	June 22	July 2	10	2	...do.....	July 11	12
3	...do.....	July 3	11	5	...do.....	July 12	13
1	...do.....	July 9	17	2	...do.....	July 13	14
21	June 23	July 2	9	2	...do.....	July 14	15
2	...do.....	July 3	10	2	...do.....	July 15	16
4	...do.....	July 4	11	5	...do.....	July 16	17
6	...do.....	July 5	12	4	July 1	July 11	10
5	...do.....	July 10	17	5	...do.....	July 12	11
1	...do.....	July 12	19	2	...do.....	July 13	12
10	June 24	July 1	7	3	...do.....	July 15	14
4	...do.....	July 5	11	1	...do.....	July 16	15
2	...do.....	July 7	13	4	July 5	July 12	7
10	June 25	July 2	7	2	...do.....	July 14	9
7	...do.....	July 5	10	2	...do.....	July 16	11
7	...do.....	July 6	11	1	...do.....	July 20	15
4	...do.....	July 7	12	1	...do.....	July 22	17
1	...do.....	July 9	14	2	July 7	July 16	9
1	...do.....	July 10	15	1	...do.....	July 17	10
1	...do.....	July 11	16	1	...do.....	July 22	15

TABLE X.—*Length of life of moths of the spring brood. Summary of Table IX.*

Number of moths.	Days per moth.	Days for total number of moths.	Number of moths.	Days per moth.	Days for total number of moths.
24	7	168	6	15	90
25	9	225	5	16	80
20	10	200	13	17	221
36	11	396	2	19	38
14	12	168			
10	13	130	161	....	1,800
6	14	84			

TABLE XI.—*Length of life of moths of the spring brood. Summary of Table IX.*

Observations.	Days.
Average....................	11.18
Maximum....................	19
Minimum....................	7

It is evident from this table that the greater number died shortly after the first week after emergence. On an average the moths lived 11 days; 2 moths lived 19 days and 24 moths lived 7 days.

THE FIRST GENERATION.

FIRST-BROOD EGGS.

Incubation period.—In the preceding pages the time and extent of egg deposition have been considered as habits of the moths. In view of the abundance of eggs laid on the apples in the cages, it was not possible to count the eggs and determine the incubation period for individual eggs. But, as shown in Table XII, records were taken at the time of hatching of the first and the last eggs of each group of apples containing eggs of a given age, which merely shows in a general way the extent of the variability during the incubation.

TABLE XII.—*First-brood eggs. Incubation period of eggs laid in rearing cages.*

No. of observation.	Date of— Deposition.	Date of— Hatching.	Days of incubation.	No. of observation.	Date of— Deposition.	Date of— Hatching.	Days of incubation.
1	June 23	June 29	6	19	July 3	July 12	9
2	June 24	...do...	5	20	July 4	...do...	8
3	June 25	July 1	6	21	July 5	...do...	7
4	...do...	July 2	7	22	...do...	July 13	8
5	June 26	...do...	6	23	July 6	...do...	7
6	...do...	July 3	7	24	July 8	July 14	6
7	June 27	July 4	7	25	...do...	July 15	7
8	...do...	July 5	8	26	July 9	...do...	6
9	June 28	July 6	8	27	July 10	...do...	5
10	June 29	July 7	8	28	...do...	July 16	6
11	...do...	July 8	9	29	July 11	...do...	5
12	...do...	July 9	10	30	...do...	July 17	6
13	June 30	July 8	8	31	July 12	July 18	6
14	July 1	July 9	8	32	...do...	July 19	7
15	...do...	July 10	9	33	July 13	July 21	8
16	...do...	July 11	10	34	July 14	...do...	7
17	July 2	...do...	9	35	...do...	July 22	8
18	...do...	July 12	10	36	July 15	...do...	7

The difference of one to two days in the time of hatching indicates an existing difference in the embryological development originating previous to the time of oviposition. Similar observations were made in 1909 by the writer with eggs of the grape root-worm which had all been laid by a single female at the same time. On hatching, these eggs showed a variation of 2 days in the time of incubation. Table XII, representing a summary of observations of the previous table, shows an average of 7.33 days for the entire egg period, with a maximum of 10 days and a minimum of 5 days.

TABLE XIII.—*Incubation period of first-brood eggs. Summary of Table XII.*

Observations.	Days of incubation.
Average	7.33
Maximum	10
Minimum	5

FIRST-BROOD LARVÆ.

As has been already stated, some of the first-brood larvæ do not transform with the rest of the brood, but spin up for the winter, hibernating along with second-brood larvæ. In the rearing of the codling moth separate observations were made for the two sets of larvæ, which are here treated separately as "transforming" and "wintering" larvæ.

Time of hatching.—In the rearing cages the first larvæ hatched June 30, but these were not from eggs of the earliest moths, as the latter failed to oviposit in captivity. Considering, however, the emergence and oviposition records of the moths, previously described, it is very probable that eggs occurred in the field on June 23 and continued to appear until the end of July. In the rearing cages the last larvæ of the brood hatched June 22, while in the field two newly hatched larvæ were found in apples as late as July 25.

Number of larvæ developing in each apple.—In the rearing of the codling moth great numbers of young larvæ entered the same apple, but when the apples were examined at the time of maturity of the larvæ only one or, rarely, two or three larvæ were found in the same fruit. In orchards usually only a single larva is found in each apple, although the apples may show several empty eggshells and entrance places of the young larvæ. The writer observed, on July 2, 1909, in the course of rearing the grape-berry moth (*Polychrosis viteana* Clemens), how a newly hatched larva devoured another of its own kind, both having emerged at about the same time. It is very probable that where larvæ of the codling moth occur in numbers many of them meet a similar fate.

Period of feeding of transforming larvæ.—In Table XXII are given the feeding periods of 53 individual larvæ which were reared in cages. On an average the larvæ remained in the fruit 26 days, a single larva remained 37 days, while the shortest period in the fruit was 17 days. (See Table XXIII.)

Period of feeding of wintering larvæ of the first brood.—On an average the wintering larvæ of the first brood remained 31 days in the fruit, while the transforming larvæ remained only 26 days. (See Table XVI.) Records of the feeding period for about 200 wintering larvæ were taken from observations in rearing cages, as shown in Table XIV.

TABLE XIV.—*Larvæ of the first brood. Feeding periods of wintering larvæ.*

Number of larvæ.	Date—		Days feeding.	Number of larvæ.	Date—		Days feeding.	Number of larvæ.	Date—		Days feeding.
	Hatched.	Left fruit.			Hatched.	Left fruit.			Hatched.	Left fruit.	
1	June 30	July 25	25	7	July 8	Aug. 5	28	1	July 13	Aug. 9	27
1	...do.....	July 28	28	1	...do.....	Aug. 6	29	4	...do.....	Aug. 10	28
1	...do.....	July 30	30	3	...do.....	Aug. 8	31	3	...do.....	Aug. 13	31
1	...do.....	July 31	31	1	...do.....	Aug. 10	33	1	...do.....	Aug. 14	32
1	...do.....	Aug. 9	40	1	...do.....	Aug. 11	34	2	...do.....	Aug. 16	34
2	...do.....	Aug. 11	42	1	...do.....	Aug. 12	35	2	...do.....	Aug. 17	35
1	...do.....	July 29	29	1	...do.....	Aug. 13	36	1	...do.....	Aug. 12	30
1	...do.....	July 30	30	1	July 9	July 28	[a] 19	2	...do.....	Aug. 15	33
1	...do.....	July 31	31	1	...do.....	Aug. 2	24	1	...do.....	Aug. 17	35
1	July 1	July 26	25	3	...do.....	Aug. 3	25	1	...do.....	Aug. 20	38
2	...do.....	July 29	28	2	...do.....	Aug. 4	26	1	July 15	Aug. 12	28
1	...do.....	July 31	30	3	...do.....	Aug. 9	31	3	...do.....	Aug. 13	29
2	...do.....	Aug. 2	32	2	...do.....	Aug. 15	37	2	...do.....	Aug. 15	31
1	...do.....	Aug. 4	34	1	...do.....	Aug. 28	50	1	...do.....	Aug. 16	32
1	...do.....	Aug. 17	47	1	July 10	July 26	[a] 16	1	...do.....	Aug. 13	29
1	July 2	July 31	29	1	...do.....	Aug. 4	25	1	...do.....	Aug. 14	30
2	...do.....	Aug. 2	31	1	...do.....	Aug. 5	26	1	...do.....	Aug. 15	31
1	...do.....	Aug. 5	34	1	...do.....	Aug. 8	29	2	...do.....	Aug. 16	32
1	...do.....	Aug. 11	40	1	...do.....	Aug. 11	32	2	...do.....	Aug. 17	33
1	...do.....	Aug. 14	43	1	July 11	July 28	[a] 17	1	...do.....	Aug. 18	34
2	July 4	July 31	27	1	...do.....	Aug. 3	23	2	...do.....	Aug. 21	37
1	...do.....	Aug. 1	28	1	...do.....	Aug. 5	25	1	...do.....	Aug. 22	38
1	...do.....	Aug. 2	29	2	...do.....	Aug. 8	28	1	...do.....	Aug. 27	43
3	...do.....	Aug. 3	30	1	...do.....	Aug. 9	29	2	July 17	Aug. 14	28
2	...do.....	Aug. 5	32	1	...do.....	Aug. 11	31	2	...do.....	Aug. 15	29
2	...do.....	Aug. 9	36	1	...do.....	Aug. 14	34	3	...do.....	Aug. 16	30
1	...do.....	Aug. 11	38	1	...do.....	Aug. 15	35	1	...do.....	Aug. 21	35
1	...do.....	Aug. 21	48	1	...do.....	Aug. 16	36	1	...do.....	Aug. 26	40
2	July 6	Aug. 2	27	1	...do.....	Aug. 18	38	1	July 19	Aug. 12	24
1	...do....	Aug. 3	28	1	July 12	Aug. 6	25	2	...do.....	Aug. 14	26
7	...do.....	Aug. 4	29	2	...do.....	Aug. 8	27	3	...do.....	Aug. 15	27
2	...do.....	Aug. 5	30	1	...do.....	Aug. 15	34	2	...do.....	Aug. 16	28
4	...do.....	Aug. 8	31	1	...do.....	Aug. 17	36	4	...do.....	Aug. 21	33
4	...do.....	Aug. 9	34	1	...do.....	Aug. 2	21	1	...do.....	Aug. 22	34
4	...do.....	Aug. 10	35	1	...do.....	Aug. 10	29	1	...do.....	Aug. 24	36
1	...do.....	Aug. 21	46	1	...do.....	Aug. 14	33	1	...do.....	Aug. 26	38
1	...do.....	Aug. 22	47	1	...do.....	Aug. 20	39	1	...do.....	Aug. 27	39
1	...do.....	Aug. 30	55	1	July 13	July 27	[a] 14	2	July 21	Aug. 16	26
1	July 8	July 25	[a] 17	1	...do.....	July 6	24	2	...do.....	Aug. 20	30
1	...do.....	Aug. 2	25	1	...do.....	July 7	25	1	...do.....	Aug. 23	33
1	...do.....	Aug. 3	26	1	...do.....	July 8	26	1	...do.....	Aug. 26	36

[a] Probably previously infested apple.

Summaries as to length of feeding for both transforming and wintering larvæ are shown comparatively in Tables XV and XVI.

TABLE XV.—*Larvæ of the first brood. Comparison of the feeding periods of transforming and wintering larvæ. Summary of Tables XIV and XXII.*

Transforming larvæ.			Wintering larvæ.		
Number of larvæ.	Days per larva.	Days for total number of larvæ.	Number of larvæ.	Days per larva.	Days for total number of larvæ.
1	[a]14	14	1	[a]14	14
....	15	....	1	[a]16	16
....	16	....	2	17	34
2	17	34	1	19	19
1	18	18	1	21	21
....	19	....	1	23	23
....	20	....	3	24	74
....	21	....	10	25	250
6	22	132	9	26	234
3	23	69	10	27	270
3	24	72	23	28	644
5	25	125	20	29	580
3	26	78	15	30	450
7	27	189	17	31	527
5	28	140	10	32	320
5	29	145	16	33	528
3	30	90	13	34	442
4	31	124	8	35	280
2	32	64	7	36	252
2	33	66	4	37	148
....	34	....	5	38	190
....	35	....	2	39	78
....	36	....	3	40	120
1	37	37	2	42	82
....	....	....	2	43	86
....	....	....	1	46	46
....	....	....	2	47	94
....	....	....	1	48	48
....	....	....	1	50	50
....	....	....	1	55	55
53	....	1,397	192	....	5,975

[a] Probably from infested apple.

TABLE XVI.—*Larvæ of the first brood. Comparison of the feeding periods of transforming and wintering larvæ. Summary of Table XV.*

Observations.	Days of feeding of—	
	Transforming larvæ.	Wintering larvæ.
Average	26.36	31.10
Maximum	37	55
Minimum	17	17

TABLE XVII.—*Larvæ of the first brood. Percentage of transforming and wintering larvæ of cage material.*

Cage No.	Number of larvæ.			Cage No.	Number of larvæ.		
	Trans-forming.	Winter-ing.	Total.		Trans-forming.	Winter-ing.	Total.
1	11	7	18	13	5	17	22
2	4	3	7	14		6	6
3	9	8	17	15		7	7
4	9	6	15	16		12	12
5	14	13	27	17		9	9
6	9	27	36	18		19	19
7	2	17	19	19	1	8	9
8	5	14	19				
9	7	6	13	Total	85	199	284
10	5	11	16				
11	2	5	7	Per cent	29.93	70.07	100.00
12	2	4	6				

Time of maturity of transforming larvæ.—From apples collected in an orchard July 8 the first larvæ emerged July 10, while from banded trees larvæ were obtained three days later. In the rearing cages the last transforming larva left the fruit August 14. (See Tables XXII and XXXIII, and fig. 22.)

Time of maturity of wintering larvæ.—Of the band record material of 1909 two larvæ, which had been collected July 19, did not transform with the rest of the brood, but remained in the larval stage and wintered. The second-brood larvæ first appear about September 10. (See fig. 22.) On examining the results of the band records, as presented in figure 21, it will be noted that the greater number of larvæ belonged to the first brood, and that the period of maturation of these larvæ extended from early July to the close of September, or perhaps even to the early part of October.

Percentages of transforming and of wintering larvæ of the first brood.—In Table XVII is given a summary of breeding experiments, showing the comparative number of transforming and wintering larvæ of the first brood. From these observations it will be found that in number the wintering larvæ exceeded the transforming larvæ about two and one-half times. These results agree closely with those obtained from the band material, which is a better test of the relative occurrence of larvæ in the field. (See Table XXXIV.) Of the first brood 23.46 per cent of the larvæ transformed and 76.54 per cent wintered. Considering the two parallel records of both cage-reared larvæ, the first brood consisted thus of one-third of transforming larvæ and two-thirds of wintering larvæ.

Larval life in the cocoon.—Cage records were kept relative to the time of leaving the fruit and the time of pupation of 52 individual larvæ. This period includes the time for the making of the cell and the so-called post-larval stage, which consists of an inactive period of one or two days, when the larva undergoes structural changes previous to pupation. A definite time limit for the post-larval stage can hardly be given, since this is a gradual change, which leads up to pupation. In Table XXII the larval life of the cocoon has been referred to under the making of the cocoon, as this constitutes the main activity of the larva during this period, but it also included the post-larval stage. The summary of the larval life in the cocoon, as recorded in Table XXIII, agrees in a striking manner with the records obtained by Mr. E. L. Jenne [a] in Arkansas in 1908. For North East, Pa., the average was 7.09 days, the maximum 19 days, and the minimum 3 days. Mr. Jenne's records show an average of 7.2 days, maximum 19 days, and minimum 3 days. In instances where the entire period previous to pupation has been recorded to last only three days, it is very probable that the larvæ, when disturbed in the process of making the cocoons, abandoned the first cocoons and made new ones. The period, therefore, appears shorter, as no record was kept of the time required in making the first cocoon.

FIRST-BROOD PUPÆ.

Time of pupation.—From infested apples, collected in an orchard July 8, mature larvæ emerged July 10 which pupated July 16. From the band material pupæ were obtained a few days later and were observed in abundance throughout the period. The last pupation occurred in the cages August 27. These late-appearing pupæ, however, failed to develop, moths emerging only from larvæ that pupated not later than August 19.

Length of first-brood pupal stage.—Of 95 pupæ of the first brood, the average duration of the stage was 12.5 days, ranging from 6 to 22 days. (See Table XX.) The records for the individual pupæ are given in Table XVIII, with a summary in Table XIX, showing variations observed in the length of the stages during the entire period when pupæ were found.

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[a] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part I.

TABLE XVIII.—*Pupæ of the first brood. Length of the pupal periods, from material collected in 1909, on banded trees.*

No.	Date of—		Days.	No.	Date of—		Days.	No.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.			Pupation.	Emergence.	
1	July 17	Aug. 2	16	33	July 28	Aug. 7	10	65	Aug. 6	Aug. 22	16
2	July 18	Aug. 3	16	34	July 29	Aug. 8	10	66	Aug. 7	Aug. 18	11
3	...do....	Aug. 2	15	35	...do....	Aug. 7	9	67	...do....	...do....	11
4	...do....	Aug. 3	16	36	...do....	Aug. 9	11	68	...do....	Aug. 19	12
5	July 19	Aug. 2	14	37	July 30	...do....	10	69	...do....	...do....	12
6	...do....	Aug. 3	15	38	...do....	...do....	10	70	...do....	Aug. 20	13
7	July 20	Aug. 2	13	39	...do....	Aug. 11	12	71	...do....	...do....	13
8	July 22	Aug. 3	12	40	...do....	Aug. 12	13	72	Aug. 8	Aug. 23	15
9	...do....	Aug. 4	13	41	July 31	Aug. 14	14	73	Aug. 9	...do....	14
10	...do....	Aug. 3	12	42	...do....	...do....	14	74	Aug. 10	Aug. 26	16
11	...do....	Aug. 4	13	43	...do....	Aug. 13	13	75	...do....	Aug. 25	15
12	...do....	Aug. 3	12	44	...do....	Aug. 11	11	76	...do....	...do....	15
13	July 23	Aug. 5	13	45	Aug. 2	Aug. 9	7	77	...do....	...do....	15
14	...do....	Aug. 4	12	46	...do....	...do....	7	78	...do....	...do....	15
15	...do....	Aug. 5	13	47	...do....	Aug. 8	6	79	...do....	...do....	15
16	...do....	...do....	13	48	Aug. 3	Aug. 11	8	80	...do....	...do....	15
17	...do....	...do....	13	49	...do....	Aug. 10	7	81	Aug. 11	Aug. 26	15
18	...do....	...do....	13	50	...do....	...do....	7	82	...do....	...do....	15
19	...do....	...do....	13	51	...do....	...do....	7	83	...do....	Aug. 27	16
20	...do....	Aug. 6	14	52	...do....	Aug. 12	9	84	...do....	Aug. 25	14
21	...do....	Aug. 5	13	53	...do....	Aug. 13	10	85	Aug. 12	Aug. 26	14
22	...do....	Aug. 4	12	54	...do....	Aug. 14	11	86	...do....	...do....	14
23	July 24	Aug. 6	13	55	...do....	...do....	11	87	...do....	...do....	14
24	July 25	...do....	12	56	...do....	Aug. 12	9	88	...do....	Aug. 25	13
25	...do....	Aug. 7	13	57	...do....	Aug. 11	8	89	...do....	Aug. 26	14
26	...do....	...do....	13	58	...do....	Aug. 13	10	90	...do....	...do....	14
27	July 26	...do....	12	59	Aug. 5	Aug. 17	12	91	Aug. 16	Aug. 30	14
28	...do....	...do....	12	60	...do....	Aug. 18	13	92	Aug. 17	Aug. 31	14
29	July 27	Aug. 8	12	61	...do....	...do....	13	93	...do....	Sept. 2	16
30	...do....	...do....	12	62	...do....	Aug. 15	10	94	Aug. 19	Sept. 6	18
31	...do....	Aug. 9	13	63	Aug. 6	Aug. 28	22	95	Aug. 23	....	......
32	July 28	Aug. 8	11	64	...do....	Aug. 20	14				
											1,185

TABLE XIX.—*Pupæ of the first brood. Variations of pupal periods. Summary of Table XVIII.*

Number of pupæ.	Pupal period (days).	Number of pupæ.	Pupal period (days).	Number of pupæ.	Pupal period (days).	Number of pupæ.	Pupal period (days).
1	6	7	10	21	13	7	16
5	7	7	11	14	14	1	18
2	8	14	12	11	15	1	22
3	9						

TABLE XX.—*Pupæ of the first brood. Length of pupal periods. Summary of Table XVIII.*

Observations.	Pupal period (days).
Average....................	12.5
Maximum..................	22
Minimum..................	6

FIRST-BROOD MOTHS.

Time of emergence.—On August 2 the earliest first-brood moths emerged from band material collected July 13. As shown in figure 20 and Table XXI, the moths gradually increased in number, reaching a maximum on August 26, at which time moths suddenly decreased, emergence ceasing altogether about September 3.

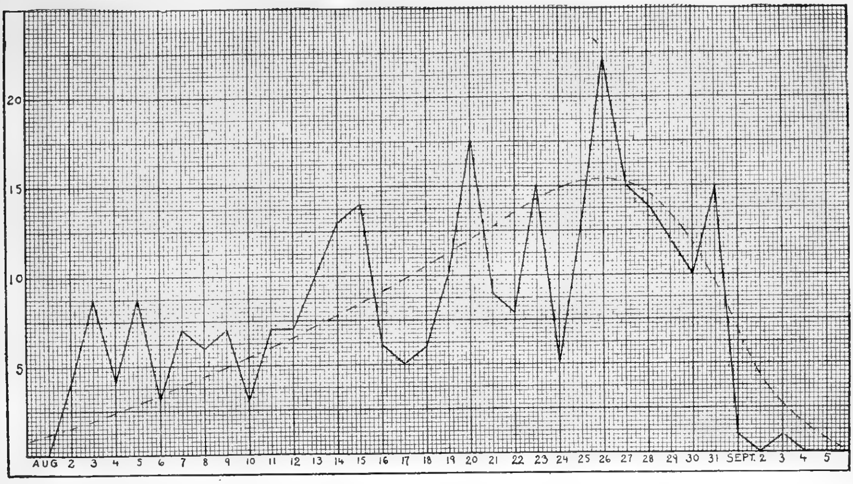

FIG. 20.—Emergence curve showing first-brood moths, in 1909, at North East, Pa. (Original.)

TABLE XXI.—*Emergence of moths of the first brood. Material from banded trees.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
Aug. 2	4	Aug. 11	7	Aug. 20	18	Aug. 28	14
Aug. 3	8	Aug. 12	7	Aug. 21	9	Aug. 29	12
Aug. 4	4	Aug. 13	10	Aug. 22	8	Aug. 30	10
Aug. 5	8	Aug. 14	13	Aug. 23	15	Aug. 31	5
Aug. 6	3	Aug. 15	14	Aug. 24	5	Sept. 2	1
Aug. 7	7	Aug. 16	7	Aug. 25	13	Sept. 3	1
Aug. 8	5	Aug. 17	5	Aug. 26	22		
Aug. 9	7	Aug. 18	6	Aug. 27	15		276
Aug. 10	3	Aug. 19	10				

It is of interest to note that the rate of emergence of the spring-brood moths is almost the reverse of the rate of emergence of the first-brood moths. In the spring, shortly after the appearance of the first moths, the maximum is attained within about a week, while the decrease in the number of moths is more gradual and extends over a longer period.

Oviposition period.—For oviposition records moths of this brood were confined in rearing jars, as has already been described for the spring brood of moths (p. 77). As shown in Table XXIV, the observations include twenty-six separate jars, in which the number of moths varied from 3 to 17 for each jar. In five of the jars no eggs were obtained, while in the rest eggs were deposited in greater or less abundance. In the summary of the oviposition records (Table XXV) it may be observed that on an average the moths first oviposited 5 days after their emergence; in one instance this period extended to 13 days; the earliest oviposition took place 2 days after emergence. The length of oviposition in the various jars lasted, on an average, 7 days, with a maximum of 15 days and a minimum of 1 day. From the time of emergence of the moth the last oviposition in the various jars took place, on an average, the eleventh day, the longest time being 19 days and the shortest 6 days. On comparing the oviposition records of observations for the two broods of moths (Tables VIII and XXV) it will be noted that the records show practically similar results.

The oviposition period extended from August 6—the fifth day after the emergence of the first moth—to September 22. Of the late deposited eggs only those laid previous to September 12 hatched, as the prevailing cold weather at that time stopped further developments.

Length of life of individual male and female moths.—In the various stock jars which were used in the oviposition experiments records were kept as to the length of life of 57 male and 92 female moths. As has already been described in connection with the spring brood, moths of the first brood were similarly fed with brown sugar and honey and received daily fresh apples and apple foliage for oviposition. Summaries of the results of these observations are given in Tables XXVI and XXVII. The average length of life for the male moths was 9.79 days, and for the female moths 11.47 days.

LIFE CYCLE OF THE FIRST GENERATION.

In connection with the various rearing experiments for the separate stages of the first generation a set of experiments was conducted, carrying individual insects through a complete life cycle. The results of these observations (see Tables XXII and XXIII) agree closely with the sum total of the averages of observations on the separate stages.

TABLE XXII.—*Life cycle of the first generation, as determined by rearing during 1909.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Total life cycle.
1	June 23	June 30	July 27	Aug. 5	Aug. 20	7	27	9	15	58
2	...do.....	...do.....	...do.....	Aug. 3	Aug. 18	7	27	7	15	56
3	...do.....	...do.....	...do.....	Aug. 2	Aug. 15	7	27	6	13	53
4	...do.....	...do.....	...do.....	...do.....	...do.....	7	27	6	13	53
5	...do.....	...do.....	July 28	Aug. 8	Aug. 23	7	28	11	15	61
6	...do.....	...do.....	...do.....	Aug. 4	Aug. 16	7	28	7	12	54
7	...do.....	...do.....	...do.....	Aug. 3	Aug. 17	7	28	6	14	55
8	...do.....	...do.....	July 29	Aug. 5	Aug. 19	7	29	7	14	57
9	...do.....	...do.....	...do.....	Aug. 9	Aug. 23	7	29	11	14	61
10	...do.....	...do.....	July 30	....	Aug. 15	7	30	....	....	53
11	June 24	...do.....	July 22	July 29	Aug. 9	6	22	7	11	46
12	...do.....	...do.....	...do.....	July 28	Aug. 11	6	22	6	14	48
13	...do.....	...do.....	...do.....	...do.....	...do.....	6	22	6	14	48
14	...do.....	...do.....	July 27	July 30	...do.....	6	27	3	12	48
15	June 25	July 1	Aug. 1	Aug. 9	Aug. 20	6	31	8	11	56
16	...do.....	...do.....	Aug. 3	...do.....	Aug. 23	6	33	6	14	59
17	June 26	July 2	July 19	July 23	Aug. 3	6	17	4	11	38
18	...do.....	...do.....	...do.....	...do.....	Aug. 5	6	17	4	13	40
19	...do.....	...do.....	Aug. 3	Aug. 9	Aug. 24	6	32	6	15	59
20	...do.....	...do.....	Aug. 8	Aug. 13	Aug. 29	6	37	5	16	64
21	June 27	July 4	July 22	July 28	Aug. 9	7	18	6	12	43
22	...do.....	...do.....	July 30	Aug. 8	Aug. 23	7	26	9	15	57
23	June 28	July 6	July 28	Aug. 2	....	8	22	5	....	....
24	...do.....	...do.....	July 29	Aug. 6	....	8	23	8	....	....
25	...do.....	...do.....	July 31	Aug. 7	....	8	25	7	....	....
26	...do.....	...do.....	Aug. 1	Aug. 6	Aug. 19	8	26	5	13	52
27	...do.....	...do.....	Aug. 3	Aug. 9	....	8	28	6	....	....
28	...do.....	...do.....	Aug. 4	Aug. 10	Aug. 25	8	29	6	15	58
29	...do.....	...do.....	Aug. 5	Aug. 8	....	8	30	3	....	....
30	June 29	July 8	Aug. 1	...do.....	Aug. 19	9	24	7	11	51
31	June 30	July 9	Aug. 2	Aug. 15	Aug. 28	9	24	13	13	59
32	...do.....	...do.....	Aug. 4	Aug. 8	....	9	26	4	....	....
33	...do.....	...do.....	Aug. 9	Aug. 11	....	9	31	2	....	....
34	...do.....	...do.....	...do.....	Aug. 26	....	9	31	17	....	....
35	...do.....	...do.....	Aug. 10	Aug. 14	....	9	32	4	....	....
36	July 1	July 10	Aug. 1	Aug. 16	Aug. 31	9	22	15	15	61
37	...do.....	...do.....	...do.....	Aug. 9	Aug. 23	9	22	8	14	53
38	...do.....	...do.....	Aug. 6	Aug. 16	Aug. 30	9	27	10	14	60
39	...do.....	...do.....	Aug. 8	Aug. 27	....	9	29	19	....	....
40	...do.....	...do.....	...do.....	Aug. 18	Sept. 3	9	29	10	16	64
41	July 2	July 11	July 25	July 31	Aug. 14	9	*a* 14	6	14	43
42	...do.....	...do.....	Aug. 5	Aug. 11	....	9	25	6	....	....
43	...do.....	...do.....	Aug. 10	Aug. 22	....	9	30	12	....	....
44	July 3	July 12	Aug. 5	Aug. 12	....	9	24	7	....	....
45	...do.....	...do.....	Aug. 14	Aug. 19	....	9	33	5	....	....
46	July 4	...do.....	Aug. 4	Aug. 8	Aug. 22	8	23	4	14	49
47	...do.....	...do.....	Aug. 6	Aug. 9	....	8	25	3	....	....
48	July 5	July 13	Aug. 7	Aug. 11	....	8	25	4	....	....
49	...do.....	...do.....	...do.....	Aug. 13	Aug. 27	8	25	6	14	53
50	...do.....	...do.....	Aug. 9	Aug. 16	....	8	27	7	....	....
51	...do.....	...do.....	Aug. 10	Aug. 14	Aug. 28	8	28	4	14	54
52	...do.....	...do.....	Aug. 13	Aug. 18	....	8	31	5	....	....
53	July 13	July 21	...do....	Aug. 23	....	8	23	10	....	....
						408	1,397	368	450	1,824

a Probably from infested apple.

TABLE XXIII.—*Life cycle of the first generation. Summary of Table XXII.*

Observations.	Days for—				
	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Total life-cycle.
Average....................	7.7	26.36	7.09	13.63	53.64
Maximum....................	9	37	19	16	64
Minimum....................	6	17	3	11	38

Since the life cycle is considered to begin with the appearance of the eggs, it becomes first completed with the appearance of eggs from moths of the same generation. The average period between the emergence of moths and first oviposition must therefore be added to the life cycle and not, as might be thought, the length of life of the moth (see Tables XXVI and XXVII). The sum total of the averages for the stages together with the average of 5 days for the oviposition (see Tables XXIV and XXV) makes 58.28 days; the average for the life cycle of individuals reared through all stages together with 5 days for oviposition was 58.68 days.

TABLE XXIV.—*Oviposition periods of moths of the first brood in rearing cages.*

Cage No.	Number of moths.	Date of—			Days—		
		Emergence of moth.	First oviposition.	Last oviposition.	Before oviposition.	Length of oviposition.	Between emergence and last oviposition.
1	4	Aug. 2	Aug. 9	Aug. 12	7	4	10
2	7	Aug. 3	Aug. 6	Aug. 9	3	4	6
3	4	Aug. 4	Aug. 7	Aug. 10	3	4	6
4	8	Aug. 5	...do.....	Aug. 20	2	14	15
5	3	Aug. 6	Aug. 13	Aug. 13	7	1	7
6	8	Aug. 7	Aug. 9	Aug. 20	2	12	13
7	3	Aug. 8	....	....	....	....	....
8	7	Aug. 9	Aug. 13	Aug. 25	4	13	16
9	4	Aug. 10	....	....	....	....	....
10	6	Aug. 11	Aug. 16	Aug. 20	5	5	9
11	3	Aug. 12	Aug. 25	Aug. 26	13	2	14
12	4	Aug. 14	....	....	....	....	....
13	4	Aug. 15	Aug. 19	Aug. 21	4	3	6
14	4	Aug. 16	Aug. 20	Aug. 26	4	7	10
15	5	Aug. 17	Aug. 24	Aug. 27	7	4	10
16	7	Aug. 18	Aug. 22	Aug. 28	4	7	10
17	12	Aug. 19	...do.....	Aug. 29	3	8	10
18	17	Aug. 20	Aug. 25	Aug. 31	5	7	11
19	10	Aug. 21	...do.....	Sept. 9	4	15	19
20	14	Aug. 23	....	....	....	....	....
21	11	Aug. 25	Aug. 28	Sept. 4	3	8	10
22	10	Aug. 27	Aug. 30	Sept. 11	3	13	15
23	9	Aug. 29	Sept. 2	Sept. 12	5	11	14
24	6	Aug. 30	....	....	....	....	....
25	4	Sept. 3	Sept. 11	Sept. 15	8	5	12
26	6	Sept. 6	Sept. 15	Sept. 22	9	8	16
					105	155	239

TABLE XXV.—*Oviposition periods of moths of the first brood. Summary of Table XXIV.*

Observations.	Days—		
	Before first oviposition.	Length of oviposition.	Between emergence and last oviposition.
Average....................	5.0	7.38	11.38
Maximum....................	13	15	19
Minimum....................	2	1	6

TABLE XXVI.—*Longevity of male and female moths of the first brood. Summary of records of 149 individual moths.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*	
2	3	2	1	14	2	14	7
3	1	3	4	15	3	15	3
4	3	4	2	16	3	16	6
5	1	5	2	17	2	17	7
6	1	6	4	18	1	18	2
7	5	7	6	....	....	19	1
8	6	8	5	....	....	20	1
9	9	9	4	....	....	21	1
10	4	10	9	....	....	22	2
11	3	11	8				
12	5	12	7		57		92
13	5	13	10				

TABLE XXVII.—*Longevity of male and female moths of the first brood. Summary of Table XXVI.*

Observations.	Life of male moths.	Life of female moths.
	Days.	*Days.*
Average....................	9.79	11.47
Maximum..................	18	22
Minimum...................	2	2

On further testing the rearing results by taking the dates of the maximum emergence of the spring brood of moths (June 24) and the emergence of moths of the first brood (August 26) it will be found that 63 days elapsed. But since the emergence of moths of the first brood was very gradual, reaching its maximum first at the close of the season (fig. 22), it becomes evident that the average of 58.5 days is fairly accurate.

THE SECOND GENERATION.

SECOND-BROOD EGGS.

Incubation period.—From two to three days after egg deposition, a semicircular red ring appears within the egg, which later disappears as the embryo attains further growth. Commonly this condition of the egg is referred to as the "red-ring" stage. A black spot appears in the egg from two to three days previous to hatching, and is caused by the dark-colored portions of the head and prothorax of the future larva which are partly visible through the eggshell. In taking observations on these features of incubation no fixed time can be given, as these changes set in and disappear gradually with the growth of the embryo or young larva. It is of value to know the significance of the "red ring" and the "black spot," as the age of the eggs can thus be approximately determined in the field.

In the cages eggs were laid daily during the entire egg-deposition period, which extended from August 6 to September 22, and a full record of the incubation period was kept during this time (Table XXVIII).

TABLE XXVIII.—*Second-brood eggs. Incubation periods of eggs laid in rearing cages.*

No. of observation.	Date.				Days.		
	Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.	Incubation.
1	Aug. 6	Aug. 8	Aug. 11	Aug. 13	2	5	7
2	Aug. 7	Aug. 9	Aug. 13	Aug. 14	2	6	7
3	Aug. 8	Aug. 10	Aug. 14	Aug. 15	2	6	6
4	Aug. 9	...do.....	Aug. 15	Aug. 16	1	6	7
5	...do....	...do....	...do....	Aug. 17	1	6	8
6	Aug. 10	Aug. 12	Aug. 16	...do....	2	6	7
7	...do....	...do....	...do....	Aug. 18	2	6	8
8	Aug. 11	Aug. 13	Aug. 18	Aug. 19	2	7	8
9	Aug. 12	Aug. 15	...do....	...do....	3	6	7
10	...do....	...do....	...do....	Aug. 20	3	6	8
11	Aug. 13	...do....	Aug. 19	Aug. 19	2	6	6
12	...do....	...do....	...do....	Aug. 20	2	6	7
13	...do....	...do....	...do....	Aug. 21	2	6	8
14	...do....	Aug. 16	...do....	Aug. 22	3	6	9
15	...do....	...do....	Aug. 20	Aug. 23	3	7	10
16	Aug. 14	Aug. 15	...do....	Aug. 21	1	6	7
17	...do....	Aug. 16	...do....	Aug. 22	2	6	8
18	...do....	...do....	...do....	Aug. 23	2	6	9
19	...do....	...do....	Aug. 21	Aug. 24	2	7	10
20	Aug. 15	Aug. 17	Aug. 22	...do....	2	7	9
21	Aug. 16	Aug. 18	Aug. 24	Aug. 25	2	8	9
22	Aug. 17	Aug. 19	...do....	...do....	2	7	8
23	Aug. 18	Aug. 21	Aug. 25	Aug. 26	3	7	8
24	...do....	...do....	...do....	Aug. 27	3	7	9
25	Aug. 19	...do....	...do....	Aug. 26	2	6	7
26	...do....	Aug. 22	...do....	Aug. 27	3	6	8
27	Aug. 20	Aug. 23	Aug. 27	Aug. 28	3	7	8
28	...do....	...do....	...do....	Aug. 29	3	7	9
29	Aug. 21	....	Aug. 28	...do....	....	7	8
30	Aug. 22	Aug. 24	...do....	...do....	2	6	7
31	...do....	...do....	...do....	Aug. 30	2	6	8
32	Aug. 23	Aug. 25	Aug. 29	Aug. 31	2	6	8
33	Aug. 24	....	...do....	Sept. 1	....	5	8
34	...do....	....	Aug. 30	Sept. 2	....	6	9
35	Aug. 25	Aug. 27	Aug. 31	Sept. 3	2	6	9
36	...do....	...do....	...do....	Sept. 4	2	6	10
37	Aug. 26	...do....	...do....	Sept. 3	1	5	8
38	...do....	...do....	...do....	Sept. 4	1	5	9
39	...do....	...do....	Sept. 1	Sept. 5	1	6	10
40	Aug. 27	Aug. 29	....	Sept. 4	2	....	8
41	...do....	...do....	....	Sept. 5	2	....	9
42	Aug. 28	Aug. 30	Sept. 8	Sept. 9	2	11	12
43	...do....	...do....	...do....	Sept. 10	2	11	13
44	...do....	Aug. 31	Sept. 9	Sept. 11	3	12	14
45	Aug. 29	...do....	...do....	...do....	2	11	13
46	...do....	...do....	...do....	Sept. 12	2	11	14
47	...do....	...do....	Sept. 10	Sept. 13	2	12	15
48	...do....	Sept. 1	...do....	Sept. 14	3	12	16
49	Aug. 30	Sept. 3	Sept. 11	Sept. 12	4	12	13
50	...do....	...do....	...do....	Sept. 13	4	12	14
51	Aug. 31	...do....	...do....	...do....	3	11	13
52	...do....	...do....	Sept. 12	Sept. 14	3	12	14
53	...do....	...do....	...do....	Sept. 15	3	12	15
54	Sept. 1	Sept. 4	...do....	Sept. 13	3	11	12
55	...do....	...do....	...do....	Sept. 14	3	11	13
56	Sept. 2	Sept. 5	Sept. 13	...do....	3	11	12
57	Sept. 3	...do....	...do....	...do....	2	10	11
58	...do....	...do....	...do....	Sept. 15	2	10	12
59	Sept. 4	Sept. 6	Sept. 14	...do....	2	10	11
60	Sept. 5	Sept. 8	...do....	...do....	3	9	10
61	Sept. 6	Sept. 10	...do....	...do....	4	8	9
62	Sept. 7	...do....	...do....	...do....	3	7	8
63	...do....	...do....	...do....	Sept. 16	3	7	9
64	Sept. 8	Sept. 11	Sept. 15	...do....	3	7	8
65	...do....	...do....	...do....	Sept. 17	3	7	9
66	...do....	...do....	Sept. 16	Sept. 18	3	8	10
67	Sept. 9	Sept. 12	...do....	Sept. 17	3	7	8
68	...do....	...do....	...do....	Sept. 18	3	7	9
69	...do....	...do....	Sept. 17	Sept. 19	3	8	10
70	Sept. 10	Sept. 13	Sept. 16	Sept. 17	3	6	7
71	Sept. 11	Sept. 14	Sept. 17	Sept. 18	3	6	7
72	...do....	...do....	...do....	Sept. 19	3	6	8
73	...do....	...do....	Sept. 18	Sept. 20	3	7	9
74	Sept. 12	...do....	Sept. 19	Sept. 21	2	7	9
75	Sept. 15	....	....	....	....	....	....
76	Sept. 18	....	....	....	....	....	....
77	Sept. 21	....	....	....	....	....	....
78	Sept. 22	....	....	....	....	....	....

The incubation period ranged from 6 to 16 days, with an average of 9.47. In the time of appearance of the red ring, the range varied from 1 to 4 days, with an average of 2.4 days. The black spot appeared on an average 7.66 days after egg deposition, and hatching generally took place from 1 to 2 days after the black spot had been observed. (Tables XXIX and XXX.)

TABLE XXIX.—*Incubation periods of second-brood eggs. Summary of Table XXVIII.*

Appearance of red ring.		Appearance of black spot.		Total incubation period.	
Number of days.	Number of observations.	Number of days.	Number of observations.	Number of days.	Number of observations.
1	6	5	4	6	1
2	32	6	26	7	12
3	30	7	19	8	20
4	3	8	4	9	16
		9	1	10	7
		10	3	11	2
		11	8	12	4
		12	7	13	5
				14	4
				15	2
				16	1

TABLE XXX.—*Incubation periods of second-brood eggs. Summary of Tables XXVIII and XXIX.*

Observations.	Number of days—		
	For appearance of red ring.	For appearance of black spot.	For incubation.
Average	2.4	7.66	9.47
Maximum	4	12	16
Minimum	1	5	6

Eggs deposited from September 15 to September 22, inclusive, failed to hatch because of prevailing cold weather.

SECOND-BROOD LARVÆ.

Time of hatching.—The extent of the hatching period of second-brood larvæ can be accurately determined, since eggs were obtained August 6 from the earliest emerging moths and subsequently almost daily until September 22. In the cages the first larvæ hatched August 13 and the last September 21; late-deposited eggs, as already stated, failed to develop because of cold weather, which limited the number of the second-brood larvæ considerably.

Feeding period.—From a number of larvæ that hatched in the cages, 100, as given in Table XXXI, developed about normally and entered hibernation.

TABLE XXXI.—*Larvæ of second brood. Periods of feeding of larvæ in rearing cages.*

No. of larvæ.	Date of— Hatching.	Date of— Leaving the fruit.	Days of feeding.	No. of larvæ.	Date of— Hatching.	Date of— Leaving the fruit.	Days of feeding.	No. of larvæ.	Date of— Hatching.	Date of— Leaving the fruit.	Days of feeding.
1	Aug. 13	Sept. 11	29	36	Aug. 19	Sept. 29	41	71	Aug. 27	Oct. 4	38
2	...do....	...do....	29	37	...do....	Oct. 8	50	72	...do....	Oct. 7	41
3	...do....	Sept. 12	30	38	...do....	Oct. 22	64	73	...do....	Oct. 8	42
4	Aug. 14	...do....	29	39	...do....	...do....	64	74	...do....	Nov. 1	66
5	...do....	Sept. 17	34	40	Aug. 20	Oct. 3	44	75	Aug. 28	Oct. 4	37
6	...do....	...do....	34	41	...do....	Oct. 10	51	76	...do....	Oct. 10	43
7	...do....	...do....	34	42	Aug. 21	Sept. 19	29	77	Aug. 29	...do....	42
8	Aug. 15	Sept. 12	28	43	...do....	...do....	29	78	...do....	Nov. 1	64
9	...do....	Sept. 13	29	44	...do....	Sept. 20	30	79	Aug. 30	Oct. 9	40
10	...do....	Sept. 16	32	45	...do....	...do....	30	80	Aug. 31	Sept. 26	[a]26
11	...do....	...do....	32	46	...do....	Sept. 23	33	81	...do....	Oct. 7	37
12	...do....	...do....	32	47	...do....	Oct. 9	49	82	...do....	Oct. 8	38
13	...do....	Sept. 17	33	48	...do....	Oct. 26	66	83	...do....	Oct. 26	56
14	...do....	...do....	33	49	Aug. 22	Sept. 17	26	84	Sept. 2	Oct. 5	33
15	...do....	Sept. 21	37	50	...do....	Sept. 19	28	85	...do....	Oct. 11	39
16	...do....	Sept. 24	40	51	...do....	Sept. 28	37	86	...do....	Nov. 2	61
17	...do....	Oct. 2	48	52	...do....	Sept. 29	38	87	...do....	Nov. 12	71
18	...do....	Oct. 8	54	53	Aug. 24	Oct. 1	40	88	Sept. 3	Oct. 1	[a]28
19	Aug. 16	Sept. 15	30	54	...do....	Sept. 28	35	89	...do....	Nov. 2	60
20	...do....	Sept. 17	32	55	...do....	Oct. 9	46	90	...do....	...do....	60
21	...do....	...do....	32	56	...do....	Oct. 23	60	91	...do....	Nov. 4	62
22	...do....	Sept. 18	33	57	Aug. 25	Sept. 22	28	92	...do....	Nov. 8	66
23	...do....	...do....	33	58	...do....	...do....	28	93	...do....	Oct. 15	73
24	...do....	...do....	33	59	...do....	Sept. 28	28	94	Sept. 4	Sept. 29	[a]25
25	...do....	Sept. 19	34	60	...do....	...do....	28	95	...do....	Oct. 3	29
26	...do....	Sept. 23	38	61	...do....	Sept. 21	27	96	...do....	Oct. 9	35
27	...do....	Sept. 26	41	62	...do....	Sept. 28	34	97	...do....	Oct. 12	38
28	...do....	...do....	41	63	...do....	Oct. 1	37	98	...do....	Oct. 15	41
29	...do....	Sept. 29	44	64	...do....	Nov. 1	60	99	...do....	Nov. 13	70
30	Aug. 17	Sept. 16	30	65	Aug. 26	Sept. 26	31	100	Sept. 5	Oct. 26	51
31	...do....	Sept. 18	32	66	...do....	Oct. 8	43	101	Sept. 10	Nov. 15	66
32	...do....	Sept. 22	36	67	...do....	Oct. 9	44				
33	Aug. 19	Sept. 17	29	68	...do....	Oct. 11	46				1,254
34	...do....	...do....	29	69	...do....	...do....	46				
35	...do....	Sept. 19	31	70	Aug. 27	Oct. 4	38				

[a] Probably from infested apple.

TABLE XXXII.—*Feeding periods of larvæ of the second brood. Summary of Table XXXI.*

Observations.	Feeding periods.
	Days.
Average	39.5
Maximum	73
Minimum	26

The feeding periods for these larvæ ranged from 26 to 73 days, with an average of 39.5 days. The feeding periods in the above records are strikingly longer than those obtained for larvæ of the first brood. This is probably due to lower temperature, which during the middle of October for 7 days brought the activities of insects to an apparent standstill.

Time of leaving the fruit for wintering.—In the cages, the first larvæ left the fruit September 11, and since these were from the earliest eggs of the first moths, these records must be approximately accurate. The length of feeding for the early larvæ of the second brood was 29 to 30 days; the larvæ hatched August 13, wintering September 11. With these established facts it is thus possible to separate the first-brood and second-brood larvæ from the banded trees, which as to time of reaching maturity overlapped considerably. (See fig. 21.) In the fall, during the alternating warm and cold days, larvæ appeared under the bands in variable numbers, as recorded in Table XXXIII. The bands were last examined November 13, when 9 larvæ were collected. In the rearing cages the last larvæ emerged November 15.

Immature larvæ at hibernation time.—It is evident from both field and rearing observations that during the latter part of November, when the temperature had already reached 20° F., quite a number of larvæ had not yet attained maturity. Of the reared larvæ that hatched September 12 several which were only one-third to one-half grown remained in the fruit, while others hatching September 21 were only one-fifth to one-sixth grown.

From the bands several undersized larvæ were collected late in the fall, and it will be of interest to know whether or not they are in condition to transform the coming spring. With the records in hand it is not possible to give the relative number of immature larvæ in the field that failed to enter hibernation places. In the cages, of 133 reared larvæ 32 remained in the fruit in the fall, and judging from their size it is doubtful if any of them could possibly attain maturity that late in the season.

BAND RECORDS OF 1909.

Through the courtesy of Mr. C. E. Luke, of North East, Pa., an apple orchard of 50 trees was obtained, which was particularly well suited for band records. The trees were about 25 years old and, to the owner's knowledge, had never been sprayed and for some time past had received no care. For several years no fruit had been gathered from the orchard. It is thus evident that for years the codling moth had developed without interference and existed under natural conditions. In 1909 most of the trees carried a heavy crop of fruit.

After the loose bark had been scraped from the trunks of 16 trees, burlap bands were placed around the main trunk in the usual manner about 3 feet from the ground. On 5 of the trees bands were also placed on the main branches, so as to obtain records as to the relative number of larvæ ascending the trees from the ground from wind-fallen fruit, as compared with the number of larvæ descending from fruit on the trees. The trees, with one exception, consisted of winter varieties, 10 of which were Golden Russet, 1 Northern Spy, 2 Greening, and 3 undetermined. Since only 16 trees of the whole orchard were banded, it is believed that the comparatively small number of first-

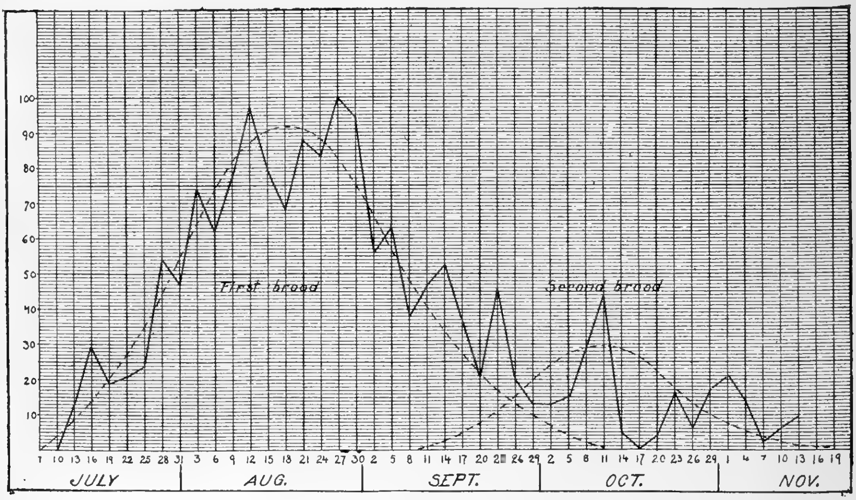

FIG. 21.—Band-record curve of 1909, at North East, Pa. (Original.)

brood larvæ which were removed had no influence upon the number of larvæ of the second brood. With the appearance of the first larvæ, July 13, the banded trees were examined every three days throughout the season until November 13. (See fig. 21.)

In comparing the number of larvæ collected from the upper and the lower bands, it will be noted (Table XXXIII) that 53 per cent were taken from the lower bands and 47 per cent from the upper bands. These figures are of interest as bearing on the effectiveness of gathering windfalls. A summary of the band records is given in Table XXXIV.

TABLE XXXIII.—*Records of larvæ collected from banded trees during 1909.*

No. of record.	Date of collecting.	Number of larvæ.			Dead or parasitized.	Number of transforming larvæ (1909).	Number of wintering larvæ.
		Upper bands (5 trees).	Lower bands (5 trees).	Total (16 trees).			
1	July 13	....	....	13	6	7	....
2	July 16	3	2	29	11	18	....
3	July 19	4	5	19	1	16	2
4	July 22	6	2	21	1	20	....
5	July 25	8	3	24	1	18	5
6	July 28	11	7	54	2	30	22
7	July 31	10	14	48	2	23	23
8	Aug. 3	22	17	74	....	51	23
9	Aug. 6	24	10	62	....	30	32
10	Aug. 9	23	15	77	....	40	37
11	Aug. 12	23	22	97	....	45	52
12	Aug. 15	15	18	79	....	3	76
13	Aug. 18	13	19	68	....	....	68
14	Aug. 21	8	30	88	....	....	88
15	Aug. 24	13	19	83	....	....	83
16	Aug. 27	18	26	100	1	....	99
17	Aug. 30	14	24	94	....	....	94
18	Sept. 2	8	11	56	....	....	56
19	Sept. 5	6	15	64	....	....	64
20	Sept. 8	7	10	38	....	....	38
21	Sept. 11	7	9	47	....	....	47
22	Sept. 14	9	7	53	....	....	53
23	Sept. 17	3	10	37	....	....	37
24	Sept. 20	4	5	21	....	....	21
25	Sept. 23	8	10	46	....	....	46
26	Sept. 26	3	4	20	....	....	20
27	Sept. 29	2	2	13	....	....	13
28	Oct. 2	4	3	13	....	....	13
29	Oct. 5	5	3	15	....	....	15
30	Oct. 8	7	6	29	....	....	29
31	Oct. 11	9	12	44	....	....	44
32	Oct. 14	1	1	5	....	....	5
33	Oct. 17	....	....	....	....	....	....
34	Oct. 20	1	1	4	....	....	4
35	Oct. 23	5	1	16	....	....	16
36	Oct. 26	2	1	6	....	....	6
37	Oct. 29	3	2	17	....	....	17
38	Nov. 1	6	8	26	....	....	26
39	Nov. 4	9	3	14	....	....	14
40	Nov. 7	....	1	2	....	....	2
41	Nov. 10	....	3	6	....	....	6
42	Nov. 13	2	5	9	....	....	9
		324	366	1,631	25	301	1,305

TABLE XXXIV.—*Records of larvæ collected from banded trees during 1909. Summary of Table XXXIII.*

Larvæ from band collections.	Percentage.
Larvæ from upper bands	46.95
Larvæ from lower bands	53.04
Transforming larvæ of band collections	18.74
Wintering larvæ of band collections	81.26
Relative proportion of first-brood larvæ	83.87
Relative proportion of second-brood larvæ	16.13
Transforming larvæ of first brood	23.46
Wintering larvæ of first brood	76.54

Few of the results here obtained have been based upon observations made during the rearing in the laboratory. For instance, the two broods of larvæ, which at the time of maturity overlap, could only be separated through rearing experiments. On comparing the two broods of larvæ it will be noted that the first brood exceeded in number the second brood about five times. Considering the number of transforming larvæ and the number of wintering larvæ of the first brood, it was found that only one-fourth of the brood completed the life cycle the same season, while three-fourths of the brood hibernated, attaining their full development with individuals of the second brood.

REVIEW OF THE LIFE-HISTORY WORK OF 1909.

During 1909 an attempt was made to rear the codling moth throughout the season, and to determine the time and relative occurrence of the different stages of the two broods. The essential results of observations for the season are shown in the diagram (fig. 22). The moths in the spring commenced to emerge June 11, reaching a maximum of emergence June 24. Moths of the following brood—the first-brood moths—appeared from August 2 to September 3, with a maximum August 26. Oviposition generally took place the fifth day after the emergence of the moths of either brood. The time during which the first brood larvæ attained maturity extended from July 10 to the end of September. Only one-fourth of the larvæ of this brood transformed and completed the life cycle the same year, while three-fourths of the larvæ hibernated. Of the second brood, mature larvæ appeared first on September 11 and continued to appear until the middle of November, at which time quite a number was prevented from further growth and failed to enter hibernation places because of prevailing low temperature. Judging by the number of larvæ collected from the banded trees, individuals of the first generation exceeded in number the second generation five times.

SEASONAL-HISTORY STUDIES OF 1907 AND 1908.

SOURCE OF REARING MATERIAL.

The rearing material for the spring of 1907 was collected from a cider bin May 9, before any larvæ had transformed. Later in the season larvæ were obtained from banded apple trees, which were then used partly the same year and partly (overwintering larvæ) for emergence records of moths the following spring. Additional band material was obtained in 1908, which, together with a small number of reared larvæ, constituted the entire supply used that year.

The rearing work for the two seasons of 1907 and 1908 was carried out on an open porch of the laboratory building, or out of doors under trees in the laboratory yard, and it is thus believed that the records of observations represent the normal transformation of the insect in orchards.

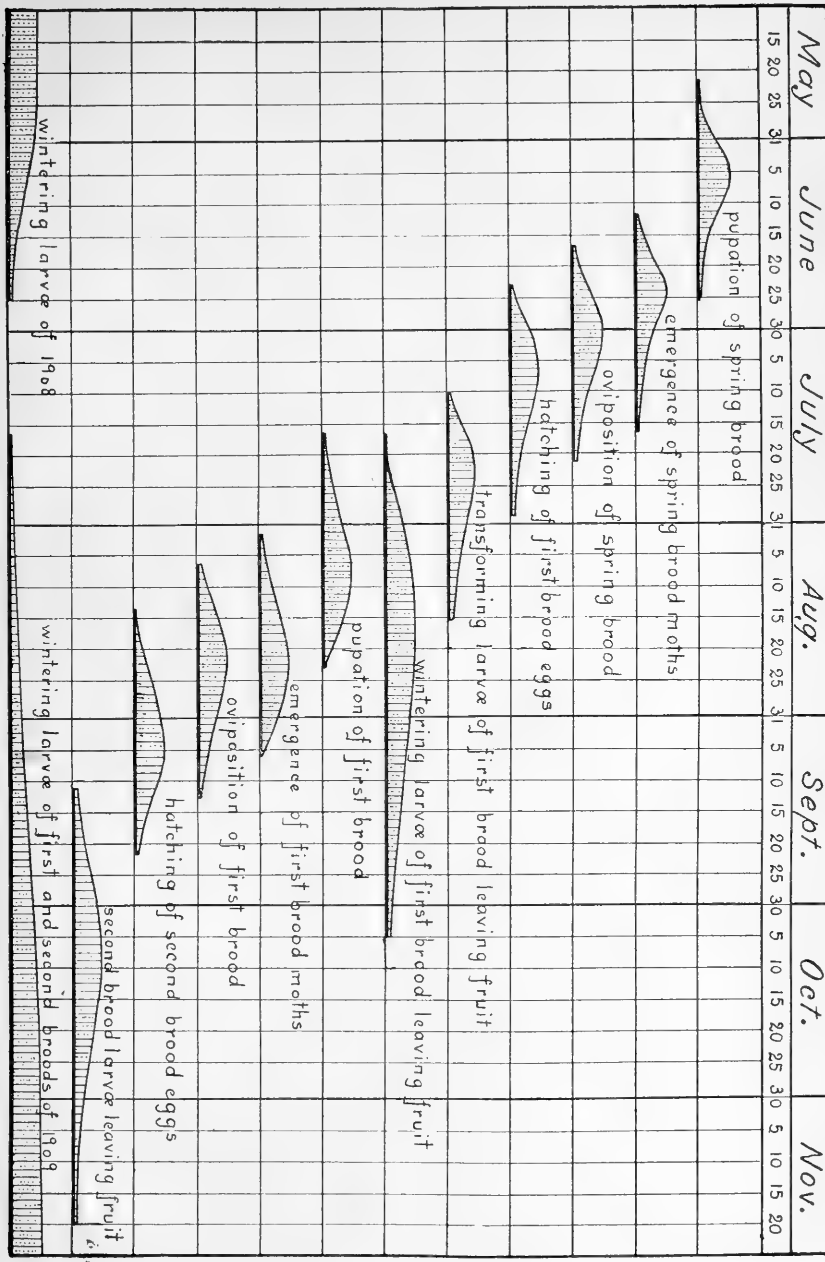

FIG. 22.—Seasonal history of the codling moth (*Carpocapsa pomonella*) as observed during 1909, at North East, Pa. (Original.)

TIME OF EMERGENCE OF MOTHS OF THE SPRING BROOD.

The first moth observed in 1907 appeared in the cages June 17 and the last July 10. The emergence period, as shown in figure 23, lasted twenty-three days, reaching a maximum on June 24. These emergence records are given in Table XXXV.

TABLE XXXV.—*Emergence of spring moths during 1907, from material collected in a cider bin.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
June 17	1	June 23	14	June 28	10	July 5	4
June 18	4	June 24	27	June 29	6	July 6	4
June 20	2	June 25	14	July 1	1	July 10	2
June 21	3	June 26	15	July 2	6		
June 22	6	June 27	3	July 3	2		124

In the spring of 1908 moths commenced to appear in the cages by May 30. The last moth of this brood emerged June 24. Unfortunately no record as to the number of emerging moths was kept, and their relative abundance can thus only be estimated. Judging by the size of a number of larvæ collected in an orchard June 10, it was evident that moths in the field must have appeared even earlier than those emerging in the cages and, on considering the band records also, it is probable that the emergence extended to the end of June.

TIME OF EMERGENCE OF MOTHS OF THE FIRST BROOD.

In 1907 the first moth emerged August 6, the maximum number emerged August 13, while the last moth appeared September 5; the emergence period was thus limited to thirty days. (See Table XXXVI and fig. 24.)

TABLE XXXVI.—*Emergence of first-brood moths during 1907. From band-collected material of 1907 and reared specimens.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
Aug. 6	1	Aug. 15	1	Aug. 21	5	Aug. 27	2
Aug. 8	2	Aug. 16	5	Aug. 22	4	Aug. 30	2
Aug. 9	1	Aug. 17	5	Aug. 23	2	Aug. 31	1
Aug. 10	5	Aug. 18	4	Aug. 24	4	Sept. 5	1
Aug. 12	5	Aug. 19	2	Aug. 25	4		
Aug. 13	18	Aug. 20	5	Aug. 26	1		80

During 1908 the emergence period was remarkably extended. In the cages the first moth emerged July 28, and the last moth emerged September 9, covering a period of forty-four days. In Table XXXVII are given the dates of emergence of the first-brood moths from band-collected material. (See also fig. 25.)

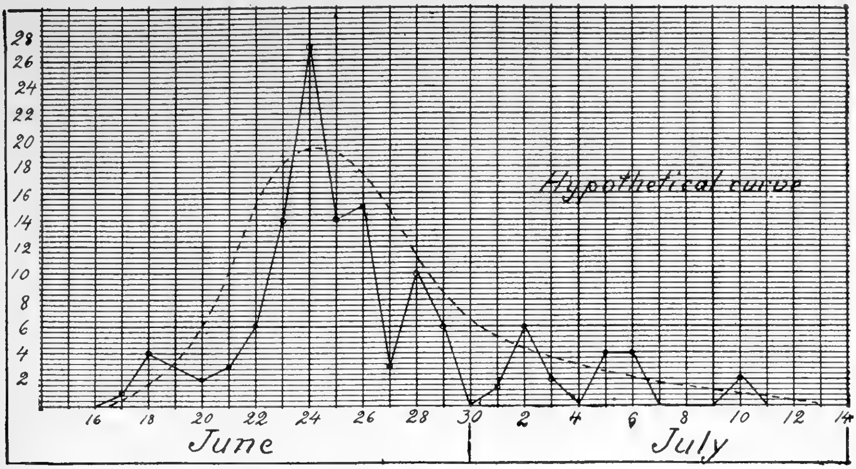

FIG. 23.—Emergence curve of spring-brood moths in 1907, at North East, Pa. Records of Mr. P. R. Jones. (Original.)

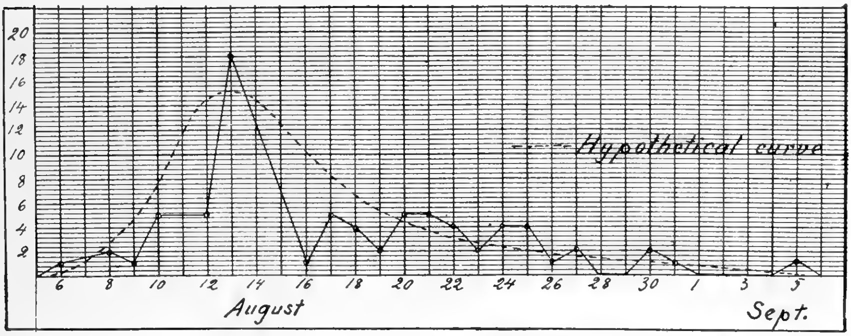

FIG. 24.—Emergence curve of first-brood moths in 1907, at North East, Pa. Records of Mr. P. R. Jones. (Original.)

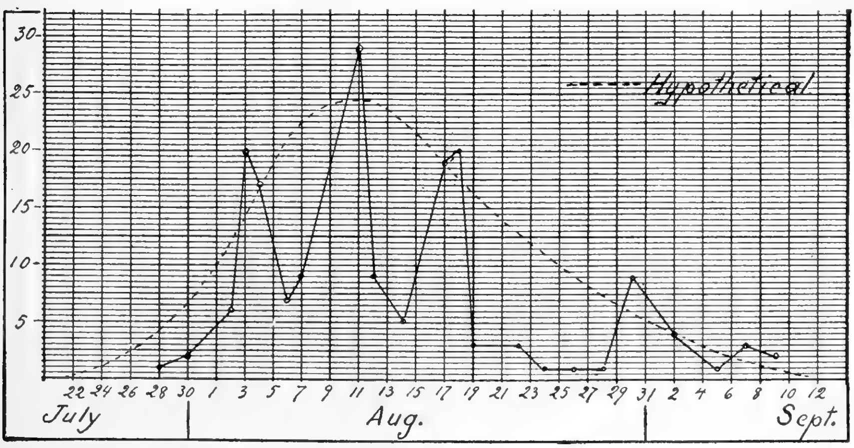

FIG. 25.—Emergence curve of first-brood moths in 1908, at North East, Pa. From band-collected material. (Original.)

TABLE XXXVII.—*Emergence of first-brood moths during 1908. From band-collected material.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
July 28	1	Aug. 7	9	Aug. 19	3	Sept. 2	4
July 31	2	Aug. 11	29	Aug. 22	3	Sept. 5	1
Aug. 2	6	Aug. 12	9	Aug. 24	1	Sept. 7	3
Aug. 3	20	Aug. 14	5	Aug. 26	1	Sept. 9	2
Aug. 4	17	Aug. 17	19	Aug. 28	1		
Aug. 6	7	Aug. 18	20	Aug. 30	9		172

BAND RECORDS OF 1907 AND 1908.

For the banding work in 1907 an unsprayed orchard was kindly placed at the disposal of the Bureau of Entomology, through the courtesy of Mr. W. Towne, of North East, Pa.

After the loose bark on the trunk and larger branches had been scraped off, 16 trees were properly banded. The banded trees were examined once a week from July 12 to November 5 for larvæ and pupæ. The results of these observations are given in Table XXXVIII.

TABLE XXXVIII.—*Band records taken from 16 apple trees during 1907.*

No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of emerging moths.	No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of emerging moths.
1	July 12	....	....	14	Sept. 21	85	....
2	July 23	....	....	15	Sept. 26	41	....
3	July 27	23	14	16	Oct. 1	25	....
4	Aug. 1	25	14	17	Oct. 6	17	....
5	Aug. 6	29	8	18	Oct. 11	9	....
6	Aug. 11	51	1	19	Oct. 16	6	....
7	Aug. 17	76	....	20	Oct. 21	10	....
8	Aug. 21	127	....	21	Oct. 26	8	....
9	Aug. 26	272	....	22	Oct. 31	9	....
10	Aug. 31	157	....	23	Nov. 5	8	....
11	Sept. 5	182	....				
12	Sept. 11	176	....			1,457	37
13	Sept. 16	121	....				

Because of the short and cool season of 1907, the great majority of the larvæ of the first brood wintered, which resulted further in a very small second generation. It is evident from figure 26 that the second-brood larvæ constituted only a small fraction of the total band collection. Since the two broods of larvæ evidently always overlap, the relative number for each brood can only be approximately estimated. Judging by the first emergence of moths of the first brood and by other rearing records of the year, the first larvæ of the second brood reached maturity about October 10. Judging by this the entire band collection would consist of 96.5 per cent of first-brood larvæ and 3.5 per cent of second-brood larvæ. Considering, further, that out of the 1,400 larvæ of the first brood only 37 individuals transformed, while the rest wintered, it can be figured approximately that only 3 per cent of the first-brood larvæ transformed, while 97 per cent wintered.

In 1908 the band-record experiments were carried out at Westfield, N. Y., in an unsprayed orchard consisting of large apple trees belonging to Mr. George Walker and kindly placed at the disposal of the Bureau of Entomology. The bands were examined once a week, and

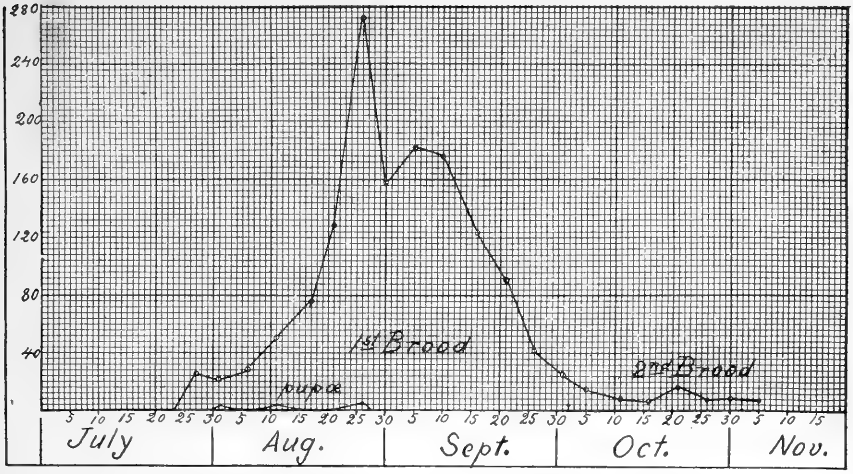

FIG. 26.—Band-record curve of 1907, at North East, Pa. (Original.)

the larvæ were counted and removed to the laboratory for further observations. As is evident from figure 27, the bands were placed on the trees about one week too late, so that no record was obtained of the earliest maturing larvæ. The two broods are here clearly dis-

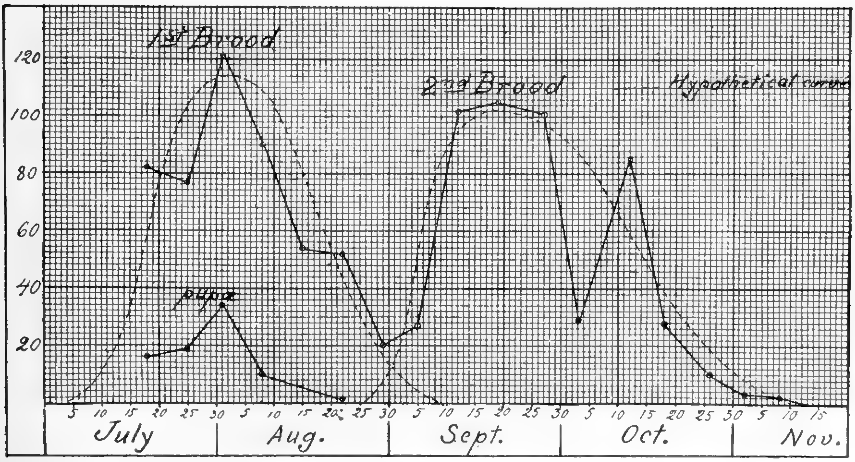

FIG. 27.—Band-record curves of 1908, at Westfield, N. Y. (Original.)

tinguishable, overlapping but slightly at the end of August. The great drop in the number of larvæ in early October (fig. 27) was due to cold weather. In Table XXXIX is given the full record of the band collections for 1908, with a summary in Table XL.

TABLE XXXIX.—*Band records taken from ten apple trees during 1908.*

No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of emerging moths.	
			1908.	1909.
1	July 18	84	66	1
2	July 25	77	69	1
3	Aug. 1	121	87	13
4	Aug. 8	90	25	27
5	Aug. 14	54	4	33
6	Aug. 22	52	1	38
7	Aug. 29	20	....	14
8	Sept. 5	27	....	25
9	Sept. 12	102	....	43
10	Sept. 19	105	....	92
11	Sept. 27	101	....	56
12	Oct. 3	29	....	26
13	Oct. 12	85	....	50
14	Oct. 18	28	....	20
15	Oct. 26	10	....	7
16	Nov. 2	6	....	2
17	Nov. 9	2	....	1
		993	252	449

TABLE XL.—*Band records of 1908. Summary of Table XXXIX.*

Larvæ from band collections.	Percentage.
Transforming larvæ of band collections	35.9
Wintering larvæ of band collections	64.1
Relative proportion of first-brood larvæ	50
Relative proportion of second-brood larvæ	50
Transforming larvæ of first brood	67.7
Wintering larvæ of first brood	32.3
Parasitized, injured, and dead larvæ	30.1

WEATHER RECORDS FOR 1907, 1908, AND 1909.

During the three seasons that the life history of the codling moth has been studied in northwestern Pennsylvania (1907–1909) daily records have been kept of the maximum and minimum temperatures, together with other climatic conditions. In preparing the temperature curves shown in figures 28–30 use has also been made of the weather records of the Weather Bureau made at Erie, Pa.

The climatic conditions have been strikingly different during the three seasons. The year 1907 was marked by an abnormally low temperature, a late spring, and an early fall with a rather high precipitation for the summer months. The month of May was the coldest on record during a period of eighteen years. In 1908, on the contrary, the spring was very early, the mean temperature was above normal, and the summer was marked by two periods of severe drought, the dry condition being especially felt during the latter part of August. In most respects 1909 was considered normal.

By comparing the daily fluctuations of temperature with the various records showing the behavior of the codling moth it will be found

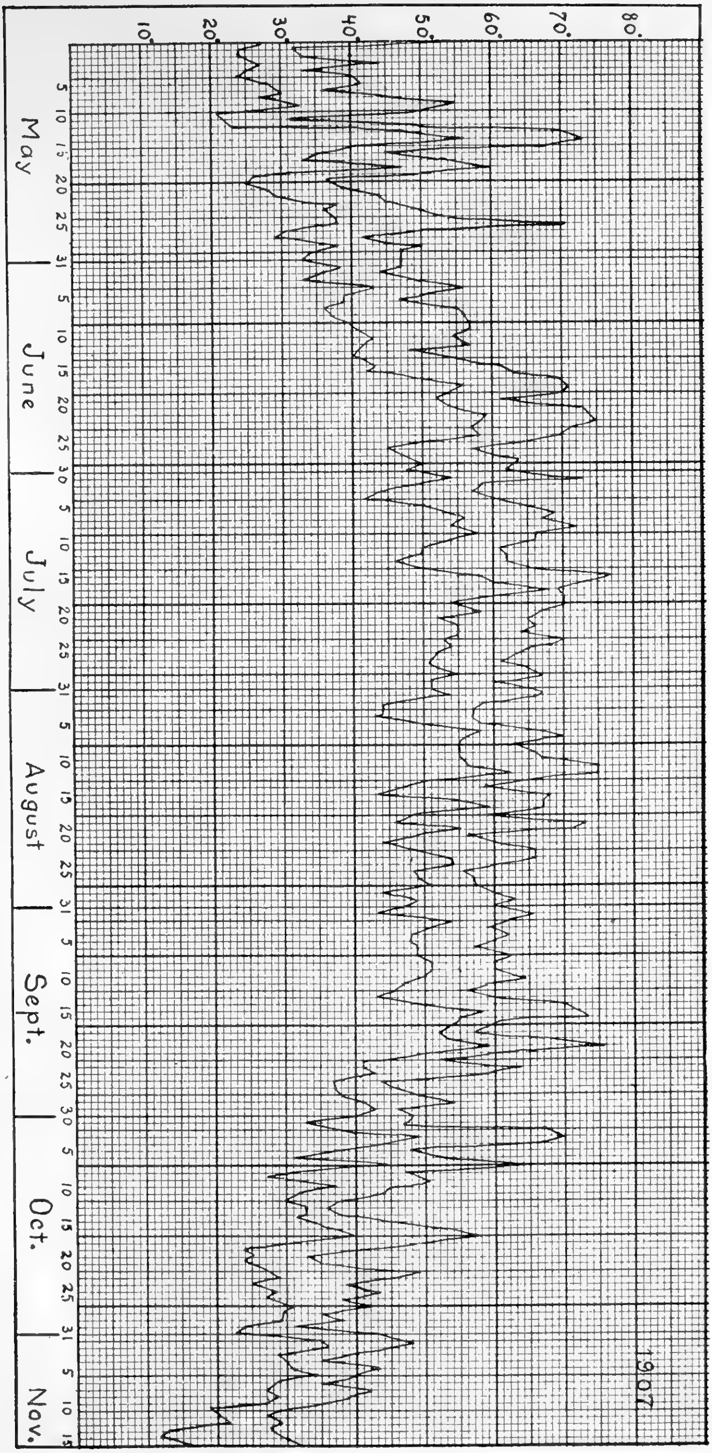

Fig. 28.—Curves showing the maximum and minimum temperature at North East, Pa., 1907. (Original.)

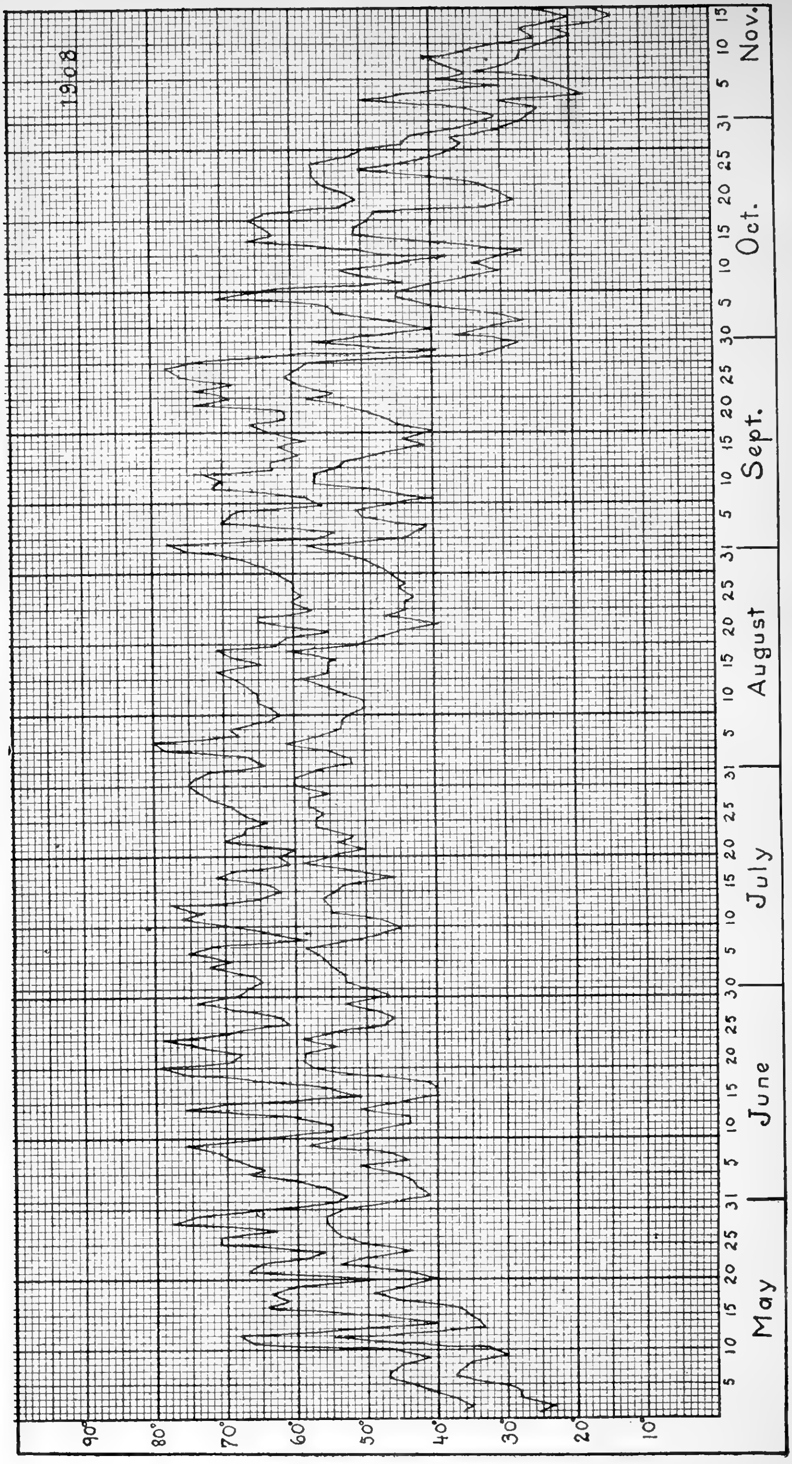

FIG. 29.—Curves showing maximum and minimum temperature at North East, Pa., 1908. (Original.)

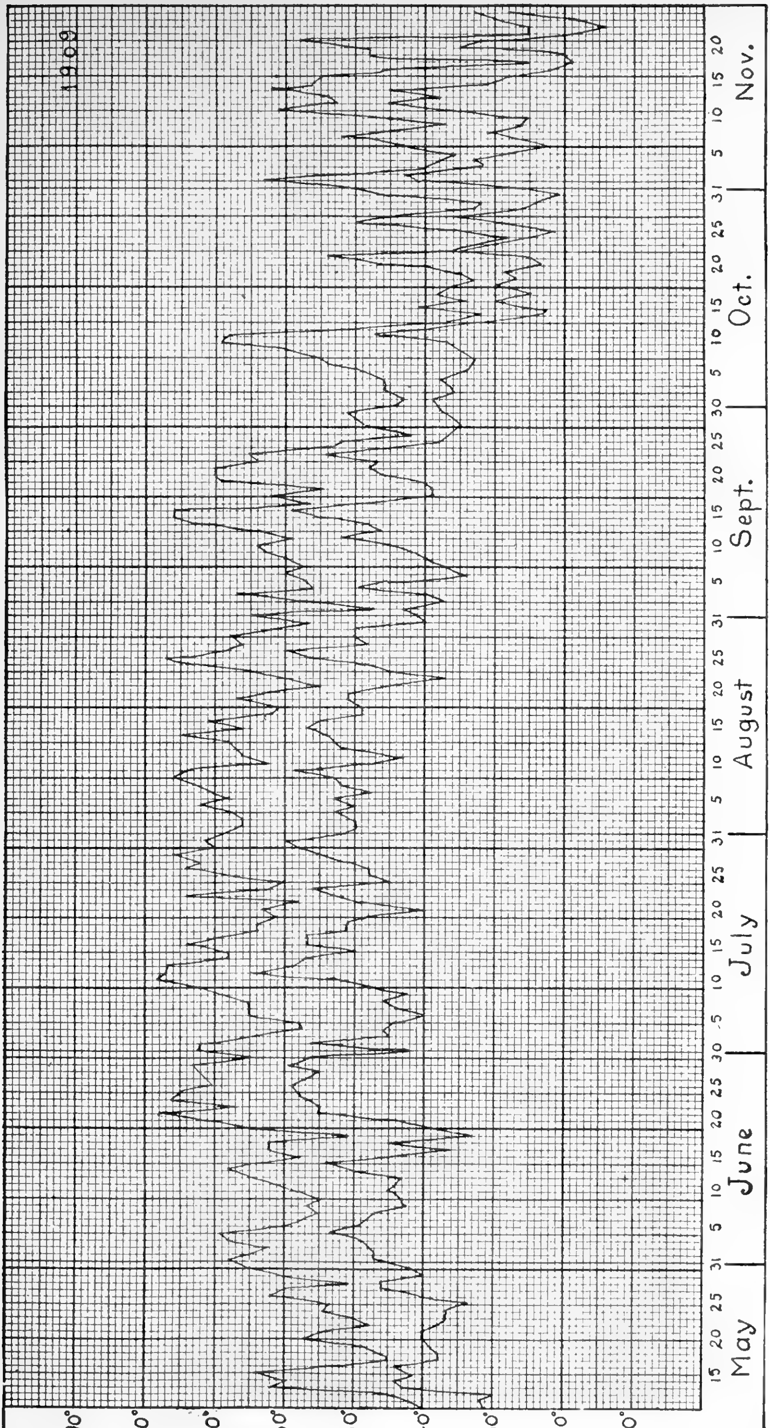

FIG. 30.—Curves showing the maximum and minimum temperature at North East, Pa., 1909. (Original.)

that its development has been greatly influenced by the temperature. A cold spell was invariably followed by a delay in transformation, while a rise in temperature produced a corresponding hastening in development.

COMPARATIVE LIFE-HISTORY STUDIES FOR THE SEASONS OF 1907, 1908, AND 1909.

On considering the records of the emergence of the moths (fig. 31) and the time of maturity and relative abundance of larvæ (fig. 32) for the three years under consideration, it is evident that the codling moth in its development is greatly influenced by seasonal conditions.

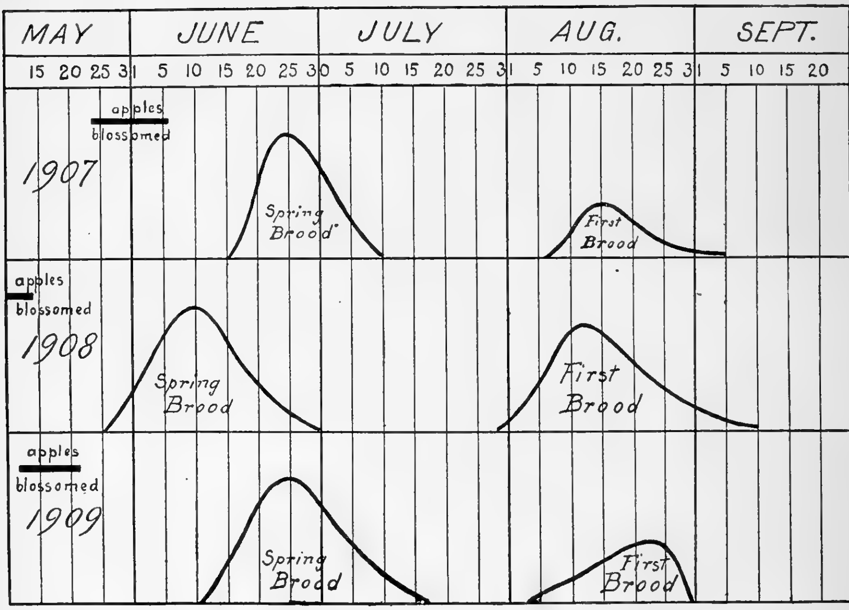

FIG. 31.—Time of emergence of spring-brood and first-brood moths, and the blossom periods of apple trees, during 1907, 1908, and 1909, at North East, Pa. (Original.)

The cold and wet spring of 1907 limited the emergence of the spring moths to a short period. The prevailing low temperature delayed the larvæ to such an extent that only 3 per cent of the first brood transformed. The entire second generation was reduced to 3.5 per cent against 96.5 per cent of the first generation.

The season of 1908 was evidently very favorable for the development of the codling moth. The early spring brought out the moths by May 25. During the long and warm summer the majority of the larvæ of the first brood transformed in great numbers (only 32.3 per cent wintered), and the following brood of larvæ attained a size equal to that of the first brood.

The development of the insect in 1909 was about intermediate as compared with the results of the previous years. The early fall was quite variable, changing frequently from warm to extremely cold, resulting in a sudden stop in the transformation of late larvæ of the first brood; the oviposition period for the second brood became limited and also late deposited eggs failed to hatch. A number of larvæ of the second brood spun up before they became full grown and several did not reach hibernating places before freezing temperature set in. Of the insects developed during 1909 83.87 per cent were of the first generation and 16.13 per cent of the second generation. Of the first-brood larvæ 23.46 per cent transformed, while 76.54 per cent

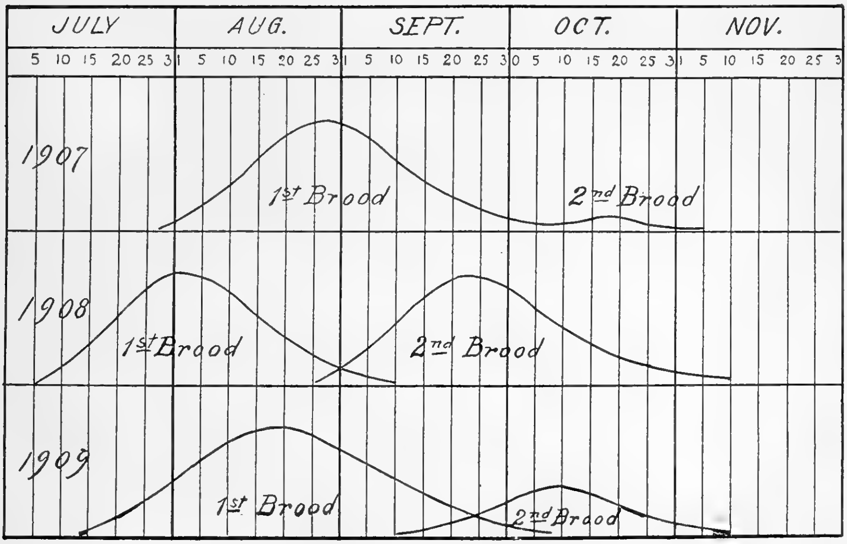

FIG. 32.—Time of leaving the fruit of the first-brood and second-brood larvæ of the codling moth, during 1907, 1908, and 1909, at North East, Pa. (Original.)

wintered. A summary of the results of life-history studies for these three years is given in Table XLI. (See also figs. 31 and 32.)

TABLE XLI.—*Summary of results of band records for 1907, 1908, and 1909, showing the comparative size of broods and relative number of transforming and wintering larvæ.*

Larvæ from band collections.	Percentages for—		
	1907.	1908.	1909.
Transforming larvæ of total band collection	2.5	35.9	18.74
Wintering larvæ of total band collection	97.5	64.1	81.26
Relative proportion of first-brood larvæ	96.5	50	83.87
Relative proportion of second-brood larvæ	3.5	50	16.13
Transforming larvæ of first brood	3	67.7	23.46
Wintering larvæ of first brood	97	32.3	76.54

INSECT ENEMIES.

The feeding habits of codling-moth larvæ within the fruit offer the insect considerable protection against both predaceous and parasitic enemies. At the time of maturity, however, when the larvæ leave the fruit and seek suitable places for transformation or hibernation, they are for a short time exposed and are sometimes attacked by various insect enemies. A small black beetle (*Tenebrioides corticalis* Melsh.) and its very slender larva were found during August to late October, 1909, under the burlap bands on apple trees. Dead and partly devoured codling-moth larvæ were frequently found attacked by both beetles and larvæ of this species. Another black beetle, *Dromius piceus* Dej., was also found quite frequently. *Platynus obsoletus* Say was taken on several occasions, and a few specimens of the larger ground beetle (*Galerita janus* Fab.) were also collected under the bands.

The following beetles were collected from banded trees, but without any observation as to their attacks upon larvæ of the codling moth: *Melanotus fissilis* Say, *Cryptarcha ampla* Er., *Mycetochares fraterna* Say, *Tenebrio tenebrioides* Beauv., and *Hymenorus* sp. These and previously named beetles were determined by Messrs. E. A. Schwarz and H. S. Barber, of the Bureau of Entomology.

The following species of ants, determined by Mr. Theo. Pergande, were found to attack the larvæ of the codling moth under the bands: *Camponotus pennsylvanicus* (Dej.) Mayr., *Formica subsericea* Say, *Cremastogaster lineolata* Say, and *Myrmica lobicornis* Nyl.

A centipede, *Geophilus rubens* Say, determined by Mr. R. V. Chamberlin, of Provo, Utah, was taken several times beneath the bands, in the act of feeding on larvæ of the codling moth.

A hymenopterous parasite (*Ascogaster carpocapsæ* Vier.), as determined by Mr. H. L. Viereck, of the Bureau of Entomology, issued in the cages from band material of the two broods of the codling moth, and proved to be quite common.

SUMMARY.

In northwestern Pennsylvania the codling moth produces in the course of a year one full generation and a partial second generation.

The life-cycle of the insect may be briefly summarized as follows: In the spring the overwintering larva pupates in early June, and three weeks later the moth emerges. The emergence extends over a period of about 1 month, beginning about the middle of June. Oviposition generally takes place 3 or 4 days after the emergence of the moth, and the egg hatches in 1 week. Eggs showing a red ring are about 3 days old, while those with a black spot in the center will mostly hatch in 1 or 2 days. Shortly after hatching the young larva enters the fruit and feeds about 26 days. On reaching maturity the larva seeks a hiding place beneath the rough bark of the trunk of the tree and constructs a cocoon within which pupation takes place about 1 week after the larva left the fruit. Some of the larvæ do not pupate at this time but winter, and the moths emerge the following spring, together with moths from second-brood larvæ. The pupal stage—called the first-brood pupæ, though the second set of pupæ of the season—lasts on an average 12 days. The emergence period of this second set of moths, called first-brood moths, begins in early August and lasts about 1 month. With the appearance of new eggs, resulting from the first-brood moths, the life-cycle of the first generation is completed, covering on an average 58 days. The second-brood eggs hatch generally within 9 days and the resulting larvæ feed about 40 days, after which they enter hibernation, making cocoons beneath the rough bark on the trunk of the trees. The life-cycle of the second generation and part of the first generation is first completed with the transformation of the insect the following spring. The period covered by the different stages of the two broods for 1909, as shown in figure 22, closely represents average conditions.

The relative number of transforming larvæ of the first brood is variable under different seasonal conditions.

The relative abundance of second-brood larvæ depends more upon seasonal conditions and food supply than upon the number of transforming larvæ of the first brood.

Larvæ of the second brood are always present in injurious numbers, so that measures should be taken to combat the second as well as the first brood.

The time of the emergence of the spring brood of the moths is variable under different seasonal conditions and depends largely upon the relative lateness of the spring.

The time of emergence of the summer brood or first brood of moths is fairly constant and generally commences about the 1st of August.

In the control of the codling moth with poison sprays three applications should be made in this section of the country. The first application should be made after the blossom period just after the petals drop, the second application 8 to 10 days later, and the third application about the 1st of August.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part VII.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

BY

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AND

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THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

By A. L. Quaintance,
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and
E. L. Jenne, E. W. Scott, and R. W. Braucher,
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INTRODUCTION.

The so-called one-spray method of spraying for the codling moth on apples consists essentially in making the application following the dropping of the petals so thorough that it will result in the practical extermination of the first brood of larvæ, subsequent treatments, therefore, becoming unnecessary. This method of spraying has come into considerable use in the Northwest following the investigations of Dr. E. D. Ball, in Utah, and Prof. A. L. Melander, in Washington, and its applicability for the control of the codling moth under eastern conditions has been strongly urged. The subject has already received attention at the hands of several eastern entomologists, notably Gossard, in Ohio, Sanderson, in New Hampshire, Felt, in New York, and Rumsey, in West Virginia. It is not within the scope of the present paper, which is in the nature of a preliminary report, to review the present status of the one-spray method. On the whole, however, it has appeared to the writers from a study of the experiments thus far reported as bearing directly upon the control of the codling moth, that most of these have been more or less inconclusive as not having fully met the conditions stated to be essential for successful one-spray work. The indispensable requisite is stated to be the placing of necessary poison in the inner calyx cup. By referring to figure 33 the structure of the calyx end of a young apple may be noted, namely, that there are two cavities, one above and one below the stamen bars or filaments. The observations of Doctor Ball led him to believe that the great majority of codling-moth larvæ in seeking entrance at the calyx end of the apple enter through the lower

calyx cup, and would thus mostly escape destruction unless the poison had been there placed. Other investigators have shown, notably the late Professor Slingerland, that codling-moth larvæ in the East feed in the outer calyx cup, and the results which have been obtained with mist sprays in the East during the past twenty-five years, filling mostly only the outer calyx cavity, have been much more favorable than could be expected were it the rule that feeding occurs principally in the inner cup. The stamen bars, as shown in the figure, form a dome or shield over the cavity below, and the poison is best forced

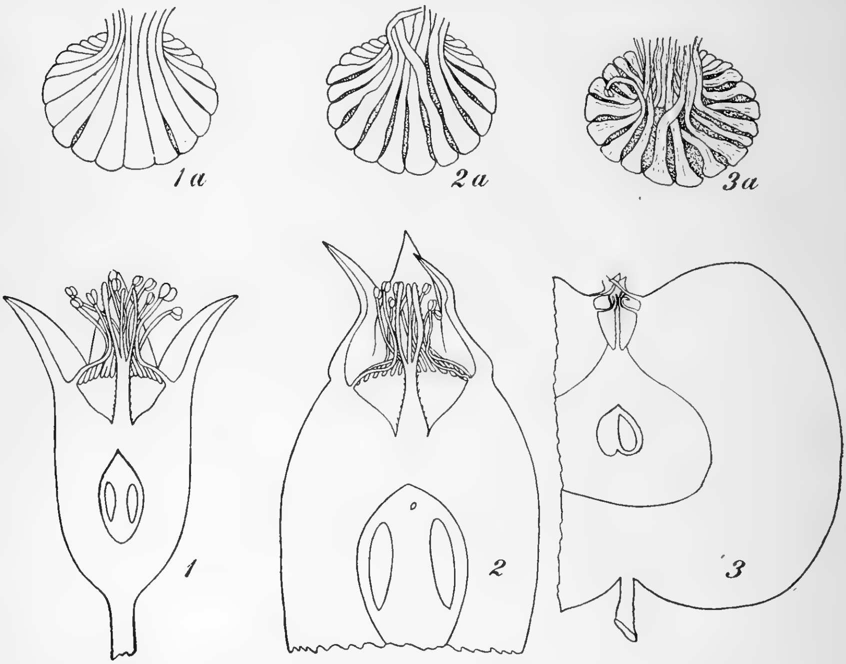

FIG. 33.—The condition of the calyx cup of the apple in relation to spraying for the codling moth: *Fig. 1.*—A calyx cup, five days after the petals fell, split open to show two cavities; *1a*, the roof of stamens as seen from above. *Fig. 2.*—A calyx cup two weeks after blossoming, showing the calyx lobes above; *2a*, the stamens from above to show spaces. *Fig. 3.*—The relation of the two cavities in a nearly grown apple; *3a*, stamens from above. (From Ball.)

through these bars by a coarse, forceful spray, as from a Bordeaux nozzle and with a pump pressure of from 175 to 200 or more pounds. It is also required that the work of spraying be done very thoroughly, the spray being directed from above into each and every fruit cluster. The use of an elbow or crook between the rod and nozzle to incline the nozzle at an angle of from 30 to 45 degrees with the spray rod permits of better directing the spray downward, and even in the case of small trees it is recommended to spray from a platform on the wagon. The employment of a coarse nozzle and a high pressure uses a large amount of spray before the trees are properly sprayed, literally drenching the trees.

This single treatment, as above described, made just after the falling of the petals, in the experience of Professor Melander has been sufficient to keep the codling moth under complete control. Doctor Ball, however, inclines to two early treatments, the second being given before the calyx lobes entirely close, as within ten days after the falling of the petals. At the time of this latter treatment the stamen bars have become more or less shriveled and more readily permit the entrance of the spray into the inner calyx cup. The two practices as recommended by Professors Ball and Melander do not differ in principle, however, and Doctor Ball's second treatment is in the nature of a supplementary one. In summing up his experiments, covering several years in Utah, Doctor Ball states his conclusions as follows:[a]

> The first early spray is the best, the second is nearly as good, and the third is of little value.
>
> Two early driving sprays will kill an average of 90 per cent of the first brood of worms.
>
> Sufficient poison is retained [in calyx cup] from the early sprayings to kill an average of 74 per cent of the second brood of worms.
>
> Two early sprayings correctly applied are worth from 6 to 16 times as much as three late ones.

Professor Melander says:[b]

> A single thorough spraying has afforded practically 100 per cent returns over hundreds and hundreds of acres of Washington orchards. The same benefit from the single spraying has also been abundantly attained in Colorado and Utah.

Aside from the particular question involved as to whether the one-spray method will sufficiently control the codling moth under eastern conditions, several other considerations must be taken into account.

In the arid valleys of the West, as in Utah, Washington, and Colorado, practically the only important insect enemy of the fruit of the apple is the codling moth, and fungous diseases are, on the whole, of but little importance. The use of fungicides is therefore not ordinarily necessary and there is thus to be controlled only the codling moth.

In the Mississippi Valley and Eastern States, however, and in central and eastern Canada, there are, in addition to the codling moth, the apple and plum curculios and the lesser apple worm, which in many sections are exceedingly injurious, the plum curculio in some parts being scarcely less in importance than the codling moth itself. Furthermore, the general prevalence of fungous diseases, such as the apple scab, apple fruit blotch, bitter rot, and leaf-spot affections, requires several fungicidal treatments during the season. Entomolo-

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[a] Bul. 67, Bur. Ent., U. S. Dept. Agr., p. 75, 1907.

[b] Journal of Economic Entomology, vol. 2, p. 67, 1909.

gists and plant pathologists have by many experiments determined a schedule of spraying with a combined arsenical insecticide and a fungicide—Bordeaux mixture or lime-sulphur wash—which affords a large degree of protection from all of these troubles. To effect the control of insects other than the codling moth and the several fungous diseases mentioned requires several applications of sprays, and renders the one-spray method of questionable practical value where these several troubles exist. These differences in fruit-growing conditions between the West and East should be borne in mind in any consideration of the practicability of the one-spray method.

RESULTS OF EXPERIMENTS WITH THE ONE-SPRAY METHOD AS COMPARED WITH RESULTS FROM THE USUAL SCHEDULE OF APPLICATIONS.

During the season of 1909 the Bureau of Entomology carried out experiments to determine the relative value, in the control of the codling moth and plum curculio under eastern conditions, of the one-spray method in comparison with a schedule of applications requiring a total of from three to five treatments according to locality, representing practically the method of spraying considered best for the localities in question. The work was carried out in three States, namely, in Virginia, in Arkansas, and in Michigan, and included four orchards, thus representing a considerable range in climatic conditions. The field work in Arkansas was under the immediate direction of Mr. E. L. Jenne, assisted by Mr. F. W. Faurot; in Virginia the field operations were under the immediate charge of Mr. E. W. Scott, assisted by Mr. L. F. Pierce, of the Bureau of Plant Industry. Mr. R. W. Braucher was charged with the spraying operations in Michigan, and was assisted a part of the time by Mr. Walter Postiff. The work relating to the control of fungous diseases in each of the orchards was done in cooperation with Mr. W. M. Scott, of the Bureau of Plant Industry. In addition to obtaining data on the effects of the treatments on the codling moth and plum curculio, in Arkansas injury by the lesser apple worm was taken into account, which in that section is very troublesome.

EXPERIMENTS IN ARKANSAS.

The experiments in Arkansas were carried out in the orchard of Mrs. S. E. Jones in the vicinity of Siloam Springs. The entire orchard, consisting of 344 trees, was divided into five plats, as shown in the accompanying diagram (fig. 34.) Trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. The orchard, a general view of which is shown in Plate X,

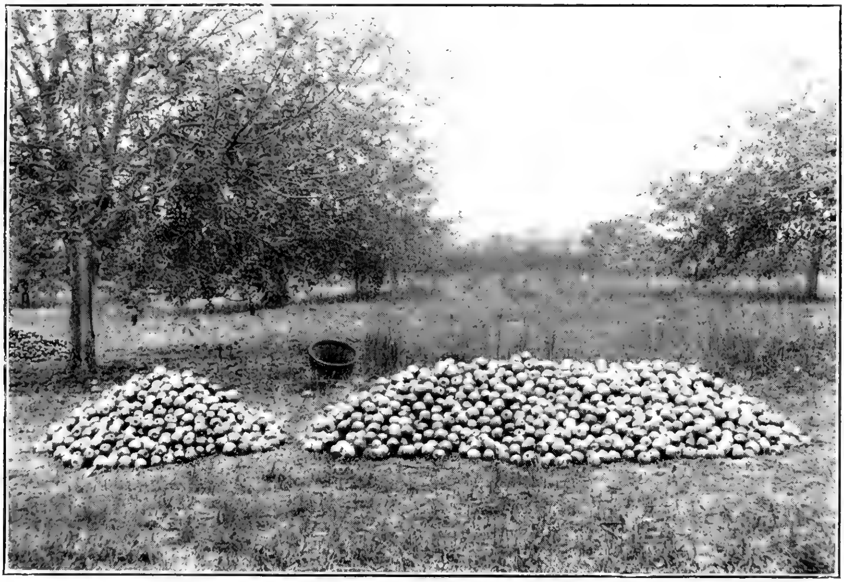

FIG. 1.—VIEW IN ORCHARD OF MRS. S. E. JONES, NEAR SILOAM SPRINGS, ARK. (ORIGINAL.)

FIG. 2.—VIEW IN ORCHARD OF MR. W. S. BALLARD, NEAR CROZET, VA. (ORIGINAL.)

figure 1, is an isolated one and the location very favorable for the work in hand. Plat I included 7 rows, Plat II a single row, Plat III 3 rows, Plat IV 5 rows, and Plat V (the unsprayed plat) included 5 rows, this last plat being at one end of the orchard. The orchard

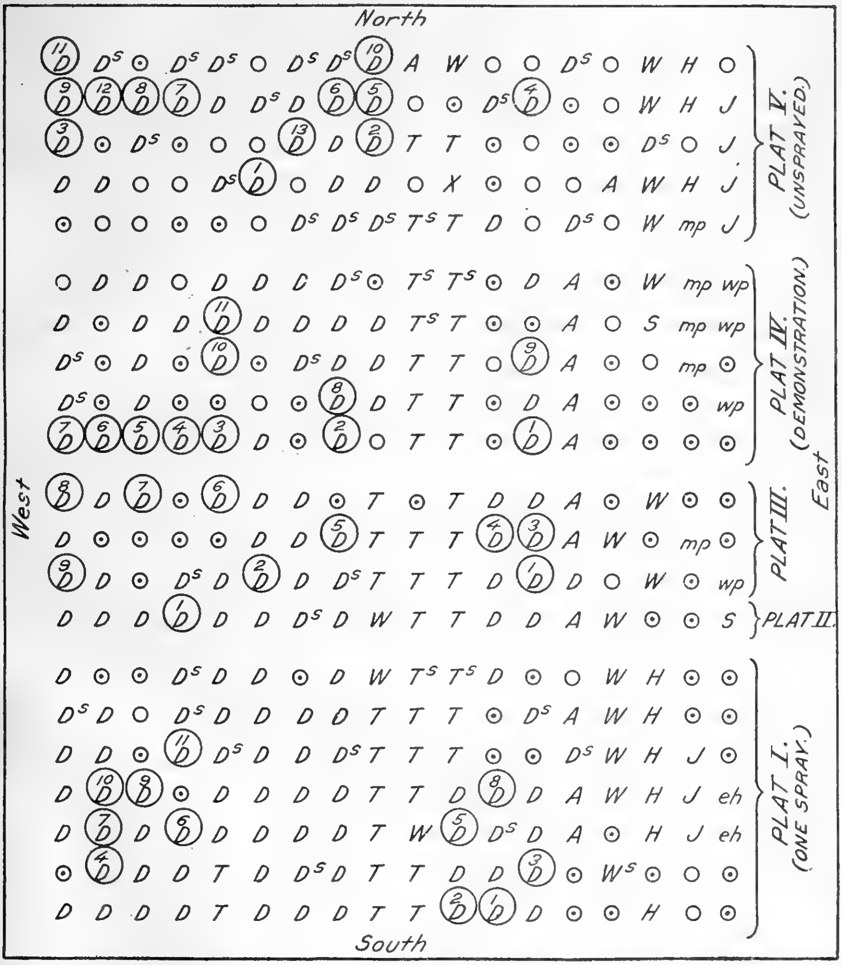

FIG. 34.—Diagram of the Mrs. S. E. Jones orchard, Siloam Springs, Ark., showing location of plats and trees used for making counts of fruit: *D*, Ben Davis variety; *A*, Arkansas Black; *T*, Mammoth Black Twig; *W*, Winesap; *J*, Jonathan; *mp*, Missouri Pippin; *wp*, White Winter Pearmain, etc. Trees of Ben Davis variety only were used for making counts of fruit. These are indicated for the respective plats by a circle, the numbers agreeing with the numbers of these trees in the tables. (Original.)

included a miscellaneous assortment of varieties, as shown by the legend under figure 34, but principally the Ben Davis, on which variety counts were made. The treatments to which the respective plats were subjected is shown in Table I.

TABLE I.—*Treatments and dates of applications of sprays for the codling moth and plum curculio. One-spray method. Siloam Springs, Ark., 1909.*

Dates of applications.	Plat I. (One-spray method.)	Plat II. (One-spray method.)
First application, April 24–25 (after falling of petals).	Drenched with arsenate of lead. 1 pound to 50 gallons of water. Bordeaux nozzles. 17 gallons per tree. 200 pounds pressure.	Drenched with arsenate of lead. 1 pound to 50 gallons Bordeaux mixture (3-3-50). Bordeaux nozzles. 17 gallons per tree. 200 pounds pressure.
Second application, May 25–26.	Bordeaux mixture only (4-4-50). Bordeaux nozzles.	Bordeaux mixture only (4-4-50). Bordeaux nozzles.
Third application, July 2.	.....do	Do.
Fourth application, July 22.	Unsprayed	Unsprayed.
Fifth application, August 10.	.....do	Do.

Dates of applications.	Plat III. (One-spray method.)	Plat IV. (Demonstration.)	Plat V. (Unsprayed.)
First application, April 24–25 (after falling of petals).	Drenched with arsenate of lead. 1 pound to 50 gallons of water. Vermorel nozzles. Mist spray. 8.3 gallons per tree. 200 pounds pressure.	Not drenched. Vermorel nozzles. Mist spray, arsenate of lead. 2 pounds to 50 gallons Bordeaux mixture (3-3-50). 11 gallons per tree. 200 pounds pressure.	Unsprayed.
Second application, May 25–26.	Bordeaux mixture only (4-4-50). Mist spray. Vermorel nozzles.	Bordeaux mixture (4-4-50) with 2 pounds arsenate of lead. Mist spray. Vermorel nozzles.	Do.
Third application, July 2.	.....do	Bordeaux mixture (4-4-50) with 2 pounds arsenate of lead. Mist spray. Vermorel nozzles.	Bordeaux mixture only (4-4-50).
Fourth application, July 22.	Unsprayed	.....do	Unsprayed.
Fifth application, August 10.	.....do	.....do	Do.

Plats I, II, and III received an arsenical treatment of 1 pound of arsenate of lead to 50 gallons of water immediately after the falling of the petals. Two subsequent applications of Bordeaux mixture only were made to protect the fruit from the apple blotch and bitter rot and one Bordeaux treatment was also given to the check plat (Plat V) for the same purpose, as these affections in this locality are exceedingly troublesome and otherwise would have interfered greatly with results. Plat IV, which received demonstration treatment, received five applications in all, as shown, of a combined spray of Bordeaux mixture and arsenate of lead, the latter being used at the rate of 2 pounds to 50 gallons of spray. On the demonstration plat the usual eddy chamber, or Vermorel nozzle, was used and while an effort was made to spray thoroughly according to usual recommendations in the East, the drenching of the trees was carefully avoided. Plat I, which received the one-spray treatment proper, was very thoroughly treated and required an average of 17 gallons per tree. The Bordeaux nozzle was used with a crook between the nozzle and spray rod and a pressure was maintained at about 200 pounds. Plat II received exactly the same treatment except that arsenate of lead was applied in dilute Bordeaux mixture to determine

to what extent russeting of the fruit might result from so liberal a use of the fungicide. The treatment for Plat III was identical with that for Plat I, except that Vermorel nozzles were used. It was desired to determine the comparative merits of a mist spray as against a coarse spray, and it will be noted that the quantity of liquids required per tree for the mist spray (Plat III) was somewhat less than one-half the amount necessary in the drenching work (Plat I).

The results presented include all of the drop fruit throughout the season and the fruit from the trees at picking time in the fall. All apples were carefully examined as to worminess from the codling moth and as to injury by the plum curculio and lesser apple worm. Fruit from Plats I and III was badly injured by the apple blotch, which can be accounted for only by the omission of Bordeaux mixture from the treatment given immediately after the falling of the petals. Fruit from Plat II, which had been thoroughly drenched with Bordeaux mixture using Bordeaux nozzles, was not noticeably more russeted than in the case of fruit from the demonstration plat and was free from apple blotch. Plat IV showed some infection from scab owing to the fact that it had not been sprayed with Bordeaux mixture before the blossoms opened.

THE CODLING MOTH.

In Table II are shown results of treatments of Plats I, III, IV, and V as to injury from the codling moth. Plat II is not here considered nor subsequently, as the point involved, namely, the effect on the fruit of a drenching spray of arsenate of lead and Bordeaux mixture after the falling of the petals, has already been indicated. There was not noticeably more russeting of the fruit on Plat II than on Plat IV which received the demonstration treatment.

TABLE II.—*Sound and wormy apples from one-spray, demonstration, and unsprayed plats. Siloam Springs, Ark., 1909.*

PLAT I. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	703	522	419	118	181	222	286	315
Sound	4,986	4,291	3,377	2,632	3,265	3,540	3,021	5,128
Total	5,689	4,813	3,796	2,750	3,446	3,762	3,307	5,443
Per cent sound	87.65	98.16	88.97	95.71	94.74	94.19	91.36	94.22

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	110	113	131			3,120	
Sound	3,489	2,539	3,764			40,032	
Total	3,599	2,652	3,895			43,152	
Per cent sound	96.95	95.71	96.69				92.76

TABLE II.—*Sound and wormy apples from one-spray, demonstration, and unsprayed plats. Slioam Springs, Ark., 1909*—Continued.

PLAT III. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	397	298	286	431	321	247	231	200
Sound	4,352	3,187	2,458	2,221	1,920	3,323	2,650	1,792
Total	4,749	3,485	2,744	2,652	2,241	3,570	2,881	1,992
Per cent sound	91.65	91.45	89.58	83.79	85.73	93.09	91.99	89.96

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	234					2,645	
Sound	1,986					23,889	
Total	2,220					26,534	
Per cent sound	89.46						90.03

PLAT IV. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	36	41	93	16	22	23	57	57
Sound	3,500	1,849	4,983	1,649	3,123	1,642	2,439	3,115
Total	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172
Per cent sound	98.99	97.83	98.17	99.04	99.31	98.62	97.72	98.21

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	154	67	41			607	
Sound	4,637	1,890	3,017			31,844	
Total	4,791	1,957	3,058			32,451	
Per cent sound	96.79	96.58	98.66				98.12

PLAT V. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	795	679	217	716	450	823	697	287
Sound	1,765	1,004	778	822	756	1,678	2,124	869
Total	2,560	1,683	995	1,538	1,206	2,501	2,821	1,156
Per cent sound	68.95	59.66	78.20	53.45	62.68	67.10	75.30	75.18

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	652	859	709	592	644	8,120	
Sound	1,671	1,399	1,010	1,016	1,416	16,308	
Total	2,323	2,258	1,719	1,608	2,060	24,428	
Per cent sound	71.94	61.18	58.76	63.19	68.74		66.74

Plat I, which received the one-spray treatment, shows an average of 92.76 per cent of fruit free from the codling moth, the percentages for individual trees ranging from 87.65 to 98.16. The total number

of apples counted from this plat was 43,152. Plat III received the drenching mist spray with Vermorel nozzle and shows for the individual trees a range in percentage of fruit free from the codling moth of 83.79 to 91.99, with an average for all trees of 90.03. There were 26,534 apples examined. Plat IV, which received the demonstration treatment of five applications, shows a total from the 11 trees of 98.12 per cent of fruit free from the codling moth, with a range for individual trees of 96.58 to 99.31 per cent, and the total number of apples counted was 32,451. Plat V (the unsprayed block) shows, for the 13 trees from which counts were made, 66.74 per cent of fruit free from the codling moth, the range being from 53.45 to 78.20 per cent, the total number of apples counted being 24,428. Demonstration plat, No. IV, shows an increase over the unsprayed trees of 31.38 per cent of uninjured fruit and an increase of 5.36 per cent of uninjured fruit over the one-spray block (Plat I).

The percentages of sound fruit from Plats I and III show very little difference in favor of a coarse spray over a mist spray; that is, 2.73 per cent in favor of the former.

In Table III are shown the places of entrance into apples of the total larvæ for the season for each tree of each plat and also the percentages, by plats, entering the fruit at the calyx, side, and stem. These data have been given in order to show what effect the methods of spraying might have upon the places of entrance into fruit by larvæ. The unsprayed plat (Plat V) may be taken to indicate the normal behavior of the larvæ and shows that of the first brood 76.84 per cent and of the second brood 80.34 per cent entered the apples at the calyx ends.

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909.*

PLAT I. ONE SPRAY.

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	......	......	......	......	......	......	......	1
Side	5	4	1	3	1	2	1	2
Stem	......	......	......	......	......	......	......	......
Total	5	4	1	3	1	2	1	3
Second brood:								
Calyx	91	70	69	20	32	31	54	55
Side	557	400	323	77	137	172	198	235
Stem	53	48	27	18	12	24	34	25
Total	701	518	419	115	181	227	286	315

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT I. ONE SPRAY—Continued.

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	2	1	......	......	......	4	15.38	....
Side	1	1	1	......	......	22	84.62	....
Stem	......	......	......	......	......	......	....	....
Total	3	2	1	......	......	26	....	....
Second brood:								
Calyx	32	24	26	......	......	504	15.97	....
Side	110	80	89	......	......	2,378	75.30	....
Stem	11	9	15	......	......	276	8.73	....
Total	153	113	130	......	......	3,158	....	3,184

PLAT III. ONE SPRAY.

Total number of larvæ and places of entrance of fruit for each tree, by broods.								
Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	2	......	......	......	......	......	1	......
Side	4	4	2	1	1	1	9	......
Stem	......	......	......	......	......	......	......	......
Total	6	4	2	1	1	1	10	......
Second brood:								
Calyx	141	103	105	158	96	70	64	66
Side	208	163	157	224	198	154	136	121
Stem	49	28	24	50	30	25	21	16
Total	398	294	286	432	324	249	221	203

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	......	......	......	......	......	3	12.00	....
Side	......	......	......	......	......	22	88.00	....
Stem	......	......	......	......	......	......	....	....
Total	......	......	......	......	......	25	....	....
Second brood:								
Calyx	74	......	......	......	......	877	33.20	....
Side	147	......	......	......	......	1,508	57.10	....
Stem	13	......	......	......	......	256	9.70	....
Total	234	......	......	......	......	2,641	....	2,666

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT IV. DEMONSTRATION.

Total number of larvæ and places of entrance of fruit for each tree, by broods.								
Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx								2
Side	1		4		1			1
Stem			2					1
Total	1		6		1			4
Second brood:								
Calyx	14	26	41	6	16	16	32	29
Side	20	14	45	10	5	7	25	21
Stem	1		3		1	1	1	3
Total	35	40	89	16	22	24	58	53

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	4	1	1			8	36.40	
Side	3					10	45.40	
Stem		1				4	18.20	
Total	7	2	1			22		
Second brood:								
Calyx	79	47	22			328	55.50	
Side	65	18	17			247	41.80	
Stem	5		1			16	2.70	
Total	149	65	40			591		613

PLAT V. UNSPRAYED.

Total number of larvæ and places of entrance of fruit for each tree, by broods.								
Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	64	102	32	132	52	96	45	25
Side	23	26	4	33	14	15	12	7
Stem	6	5	1	5	10	6	7	4
Total	93	133	37	170	76	117	64	36
Second brood:								
Calyx	579	464	139	463	295	588	513	197
Side	102	67	34	69	58	125	94	49
Stem	28	23	7	26	18	31	32	6
Total	709	554	180	558	371	744	639	252

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT V. UNSPRAYED—Continued.

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	31	258	55	63	133	1,088	76.84	....
Side	9	36	19	23	33	254	17.94	....
Stem	2	12	4	1	11	74	5.27	....
Total	42	306	78	87	177	1,416	....	....
Second brood:								
Calyx	489	458	535	398	353	5,471	80.34	....
Side	98	89	81	94	96	1,056	15.51	....
Stem	28	11	29	29	15	283	4.15	....
Total	615	558	645	521	464	6,810	....	8,226

In the case of the sprayed plats, as would be expected, the proportion entering at the calyx is greatly reduced, and there is a corresponding increase in the proportion entering the fruit at the side and stem. There is considerable variation, however, as to the number of larvæ entering the fruit at the calyx, side, and stem in the several sprayed plats, which is of significance in connection with the character of the treatments given. To better compare these points, Table IV has been prepared, which requires but little in the way of comment. A comparison of Plats I and III, both involving the one-spray method, shows, as to calyx entrance for the two broods, a difference in favor of a coarse as against a mist spray of 17.05 per cent in lessening calyx entrance and a corresponding increase in number entering at side. As between Plats I and IV a still more marked difference is shown, namely, 38.85 per cent in favor of a coarse drenching spray in preventing entrance at the calyx.

TABLE IV.—*Places of entering apples, shown in percentages, of total larvæ of first and second broods of the codling moth and of these broods combined. Siloam Springs, Ark., 1909.*

Plat number.	First brood.				Second brood.			
	Calyx.	Side.	Stem.	Total.	Calyx.	Side.	Stem.	Total.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
I	15.38	84.62	....	100.00	15.97	75.30	8.73	100.00
III	12.00	88.00	....	100.00	33.20	57.10	9.70	100.00
IV	36.40	45.40	18.20	100.00	55.50	41.80	2.70	100.00
V	76.84	17.94	5.22	100.00	80.34	15.51	4.15	100.00

TABLE IV.—*Places of entering apples, shown in percentages, of total larvæ of first and second broods of the codling moth and of these broods combined. Siloam Springs, Ark., 1909*—Continued.

Plat number.	First and second broods combined.				Total larvæ, first brood.	Total larvæ, second brood.	Total larvæ, first and second broods.
	Calyx.	Side.	Stem.	Total.			
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
I	15.96	75.38	8.66	100.00	26	3,158	3,184
III	33.01	57.39	9.60	100.00	25	2,641	2,666
IV	54.81	41.93	3.26	100.00	22	592	613
V	79.73	15.93	4.34	100.00	1,416	6,810	8,226

In order to determine what effect the respective treatments might have on the proportion of fruit which dropped and that which remained on the trees until picking time the following table (Table V) was prepared from the data in the previous tables:

TABLE V.—*Comparison of amounts of drop-fruit during season on the several plats, Siloam Springs, Ark., 1909.*

Plat number.	No. trees.	Fruit from ground.							
		First brood.				Second brood.			
		Wormy.	Sound.	Total.	Per cent sound.	Wormy.	Sound.	Total.	Per cent sound.
I	11	26	10,202	10,228	99.74	1,449	7,663	9,112	84.09
III	9	25	5,314	5,339	99.53	1,249	5,997	7,246	82.76
IV	11	22	8,970	8,992	99.74	240	5,513	5,753	95.82
V	13	945	8,109	9,054	89.56	5,471	5,742	11,213	51.20

Plat number.	No. trees.	Fruit from tree.				Total fruit.				Percentage of drop-fruit.
		Wormy.	Sound.	Total.	Per cent sound.	Wormy.	Sound.	Total.	Per cent sound.	
I	11	1,645	22,167	23,812	93.09	3,120	40,032	43,152	92.76	44.81
III	9	1,371	12,578	13,949	90.17	2,645	23,889	26,534	90.03	47.42
IV	11	345	17,361	17,706	98.05	607	31,844	32,451	98.12	45.43
V	13	1,704	2,457	4,161	59.04	8,120	16,308	24,428	66.76	82.96

As will be noted, the highest percentage of drop-fruit was on the unsprayed plat, namely, 82.96, with 47.42 per cent drop-fruit from Plat III. Plats I and IV (the one-spray and demonstration treatments) show a difference in favor of the demonstration plat of only 0.62 per cent, an amount practically negligible. The percentage of drop-fruit, including fallen fruit from all causes, is shown, but it should be remembered that fruit from all plats, except the check, was largely protected from fungous troubles by applications of Bordeaux mixture.

THE PLUM CURCULIO.

Throughout the season the drop-fruit and the fruit on trees at picking time from four of the plats in the Jones orchard were carefully examined as to injury by the plum curculio. The results of examinations are given in detail in Table VI.

TABLE VI.—*Injury by plum curculio for entire season on Plats I, III, IV, and V, sprayed in the codling-moth experiments, Siloam Springs, Ark., 1909.*

PLAT I. ONE-SPRAY.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
No. punctures	1,979	1,713	2,613	683	268	1,012	638	1,200
No. fruit punctured	1,179	915	687	387	208	532	370	706
No. sound fruit	4,510	3,898	3,109	2,363	3,238	3,236	2,937	4,737
No. fruit	5,689	4,813	3,796	2,750	3,446	3,768	3,307	5,443
Per cent free from injury	79.27	80.98	81.90	85.92	93.96	85.88	88.81	87.02

	Number of punctured and sound fruit, etc. per tree in each plat					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
No. punctures	642	319	642	......	......	11,709	......
No. fruit punctured	364	216	335	......	......	5,899	......
No. sound fruit	3,280	2,436	3,560	......	......	37,304	......
No. fruit	3,644	2,652	3,895	......	......	43,203	......
Per cent free from injury	90.01	91.85	91.39	......	......	......	86.34

PLAT III. ONE-SPRAY.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
No. punctures	2,321	721	919	788	560	1,790	1,756	732
No. fruit punctured	1,051	349	533	368	358	795	727	372
No. fruit free from injury	3,698	2,339	2,211	2,284	1,883	2,775	2,154	1,620
No. fruit	4,749	2,688	2,744	2,652	2,241	3,570	2,881	1,992
Per cent free from injury	77.86	87.01	80.57	86.12	84.02	77.73	74.76	81.32

	Number of punctured and sound fruit, etc., per tree in each plat					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
No. punctures	1,629	......	......	......	......	11,216	......
No. fruit punctured	727	......	......	......	......	5,280	......
No. fruit free from injury	1,493	......	......	......	......	20,457	......
No. fruit	2,220	......	......	......	......	25,737	......
Per cent free from injury	67.25	......	......	......	......	......	79.48

TABLE VI.—*Injury by plum curculio for entire season on Plats I, III, IV, and V, sprayed in the codling-moth experiments, Siloam Springs, Ark., 1909*—Continued.

PLAT IV. DEMONSTRATION.

Number of punctured and sound fruit, etc., per tree in each plat.								
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
No. punctures	1,293	562	773	98	430	432	1,025	877
No. fruit punctured	746	301	437	74	266	200	498	467
No. fruit free from injury	2,790	1,589	4,639	1,591	2,879	1,465	1,998	2,705
No. fruit	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172
Per cent free from injury	78.90	84.07	91.39	95.55	91.54	87.98	80.04	85.27

Number of punctured and sound fruit, etc., per tree in each plat.						Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
No. punctures	3,129	254	1,429	....	....	10,302	....
No. fruit punctured	1,656	140	769	....	....	5,554	....
No. fruit free from injury	3,135	1,817	2,289	....	....	26,897	....
No. fruit	4,791	1,957	3,058	....	....	32,451	....
Per cent free from injury	65.43	92.84	74.85	....	....	....	82.88

PLAT V. UNSPRAYED.

Number of punctured and sound fruit, etc., per tree in each plat.								
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
No. punctures	6,623	6,230	4,331	10,068	3,372	9,527	14,727	4,714
No. fruit punctured	2,130	1,595	948	1,522	999	2,299	2,724	1,070
No. fruit free from injury	430	106	47	16	207	202	97	86
No. fruit	2,560	1,701	995	1,538	1,206	2,501	2,821	1,156
Per cent free from injury	16.79	6.23	4.72	1.04	17.16	8.07	3.43	7.43

Number of punctured and sound fruit, etc., per tree in each plat.						Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
No. punctures	6,143	8,707	6,921	5,984	6,739	94,086	....
No. fruit punctured	1,936	2,117	1,605	1,517	1,750	22,212	....
No. fruit free from injury	387	141	114	91	310	2,234	....
No. fruit	2,323	2,258	1,719	1,608	2,060	24,446	....
Per cent free from injury	16.65	6.24	6.63	5.65	15.04	....	8.85

All punctures, whether egg or feeding, are classed together under "Number punctures." The total percentage of fruit free from curculio injury includes fruit entirely free from feeding and egg punctures, and has no reference to injury from other insects, as the codling moth or lesser apple worm. Curiously, in the Siloam Springs work the one-spray block (Plat I) shows the maximum percentage of fruit free from curculio attack, injury on the demonstration plat exceeding in this regard that on the one-spray plat by 3.46 per cent. It should be noted, however, that Plat IV was adjacent to the unsprayed block (see fig. 2) and there was unquestionably considerable overflow of curculio, as on this latter the beetles were quite abundant, as shown by the low total percentage of uninjured fruit, namely, 8.85 per cent. In view of the habits of the curculio in ovipositing and feeding over a considerable period (six to eight weeks or more), the results from the one-spray method are the more surprising, and it would appear that the single treatment resulted in their almost complete destruction.

In Table VII are brought together data showing the effects of the treatments in the control of the three principal insect enemies of the fruit, namely, the codling moth, the plum curculio, and the lesser apple worm (*Enarmonia prunivora* Walsh). The value of the one-spray method is here put to the severest possible test so far as controlling insect enemies of the fruit is concerned. It will be noted that when these three insects are taken into account somewhat better results were secured from Plat IV, which received the demonstration treatment, namely, 81.19 per cent sound fruit, as against 79.60 per cent sound fruit from the one-spray plat. The unsprayed plat (V) shows a very low percentage of fruit free from injury by these three insects, namely 6.94 per cent.

TABLE VII.—*Effect of treatments on the three principal fruit insects and total percentage of sound fruit. Siloam Springs, Ark., 1909.*

PLAT I. ONE-SPRAY.

Character of injury.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	1,179	915	687	387	208	532	370	706
Injured by codling moth	703	522	419	118	181	222	286	315
Injured by lesser apple worm	71	74	41	6	31	17	19	30
Number injured apples	1,778	1,403	1,062	486	409	739	652	991
Number uninjured apples	3,911	3,410	2,734	2,264	3,037	3,023	2,655	4,452
Total number apples	5,689	4,813	3,796	2,750	3,446	3,762	3,307	5,443

Character of injury.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	364	216	335	......	......	5,899	86.34	....
Injured by codling moth	110	113	131	......	......	3,120	92.74	....
Injured by lesser apple worm	10	5	5	......	......	309	.71	....
Number injured apples	473	349	460	......	......	8,802	....	....
Number uninjured apples	3,126	2,303	3,433	......	......	34,348	....	79.60
Total number apples	3,599	2,652	3,895	......	......	43,152	....	....

PLAT III. ONE-SPRAY.

Character of injury.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	1,051	349	533	368	358	795	727	372
Injured by codling moth	397	298	286	431	321	247	231	200
Injured by lesser apple worm	29	19	14	32	40	22	26	12
Number injured apples	1,363	525	772	806	684	1,010	919	551
Number uninjured apples	3,386	2,960	1,972	1,846	1,557	2,560	1,962	1,441
Total number apples	4,749	3,485	2,744	2,652	2,241	3,570	2,881	1,992

TABLE VII.—*Effect of treatments on the three principal fruit insects and total percentage of sound fruit. Siloam Springs, Ark., 1909*—Continued.

PART III. ONE-SPRAY—Continued.

Character of injury.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	727					5,280	79.48	
Injured by codling moth	234					2,645	90.03	
Injured by lesser apple worm	9					203	.76	
Number injured apples	786					7,416		
Number uninjured apples	1,434					19,118		72.05
Total number apples	2,220					26,534		

PLAT IV. DEMONSTRATION.

Character of injury.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	746	301	437	74	266	200	498	467
Injured by codling moth	36	41	93	16	22	23	57	57
Injured by lesser apple worm	6	1	6	1	0	2	3	0
Number injured apples	826	332	509	90	287	222	545	518
Number uninjured apples	2,710	1,558	4,567	1,575	2,858	1,443	1,951	2,654
Total number apples	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172

Character of injury.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	1,656	140	769			5,554	82.88	
Injured by codling moth	154	67	41			607	98.12	
Injured by lesser apple worm	14	6	3			42	.13	
Number injured apples	1,761	207	806			6,103		
Number uninjured apples	3,030	1,750	2,252			26,348		81.19
Total number apples	4,791	1,957	3,058			32,451		

PLAT V. UNSPRAYED.

Character of injury.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	2,130	1,595	948	1,522	999	2,299	2,724	1,070
Injured by codling moth	795	679	217	716	450	823	697	287
Injured by lesser apple worm	213	140	52	222	89	224	309	91
Number injured apples	2,250	1,605	959	1,528	1,072	2,355	2,740	1,076
Number uninjured apples	310	78	36	10	134	146	81	80
Total number apples	2,560	1,683	995	1,538	1,206	2,501	2,821	1,156

Character of injury.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	1,936	2,117	1,605	1,517	1,750	22,212	8.85	
Injured by codling moth	652	859	709	592	644	8,120	66.75	
Injured by lesser apple worm	120	218	139	174	77	2,068	8.50	
Number injured apples	1,987	2,148	1,631	1,556	1,824	22,731		
Number uninjured apples	336	110	88	52	236	1,697		6.94
Total number apples	2,323	2,258	1,719	1,608	2,060	24,428		

EXPERIMENTS IN VIRGINIA.

The experiments in Virginia were carried out in two localities, namely, at Crozet, in the orchard of W. S. Ballard, and at Mount Jackson, in the orchard of the Strathmore Orchard Company.

W. S. Ballard's Orchard.

W. S. Ballard's orchard is located in the eastern foothills of the Blue Ridge Mountains and is composed mostly of the Yellow Newtown (Albemarle Pippin) variety, which sort was used exclu-

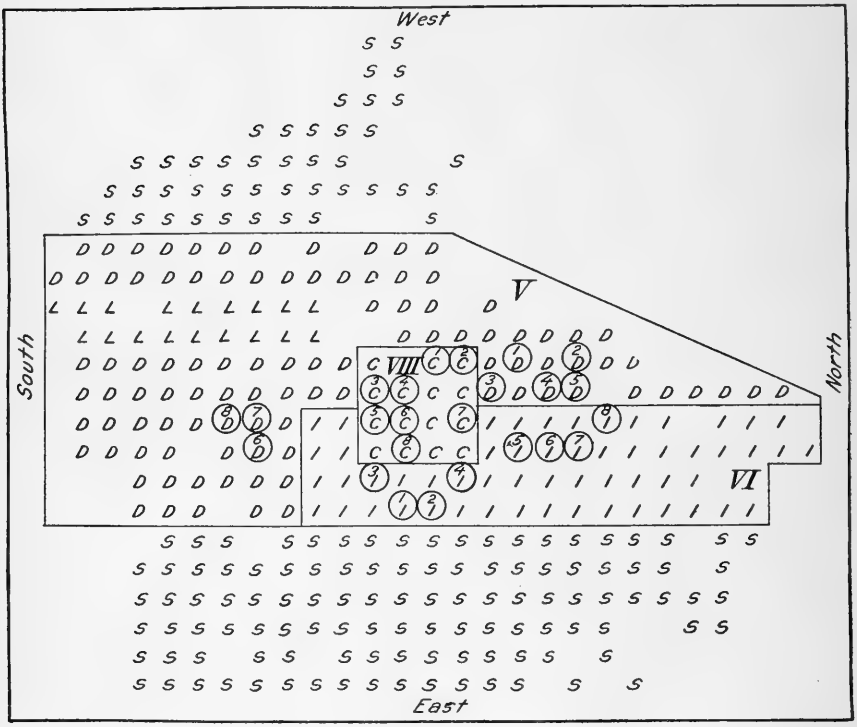

FIG. 35.—Diagram showing arrangement of plats and trees in the W. S. Ballard orchard near Crozet, Va. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Variety, Yellow Newtown (Albemarle Pippin). Trees marked *S* sprayed by owner. (Original.)

sively in the experiments. The location of the trees sprayed, with reference to adjacent trees in the orchard, is shown in figure 35. The surrounding trees not included in the experiment were sprayed by the owner. The size of the trees and general character of the location are shown in Plate X, figure 2.

THE CODLING MOTH.

The treatments given and dates of applications are shown in Table VIII.

TABLE VIII.—*Dates of applications for codling moth and plum curculio, one-spray method. Crozet, Va., 1909.*

Date of application.	Plat V. (Demonstration.)	Plat VI. (One spray method.)	Plat VIII. (Unsprayed.)
First application, April 27 (after falling of petals).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead 2 pounds to 50 gallons Bordeaux mixture (2-2-50). Pressure 120 to 140 pounds.	Drenched with arsenate of lead 2 pounds to 50 gallons Bordeaux mixture (2-2-50). Pressure 125-160 pounds. Seneca nozzles. 11 gallons per tree.	Unsprayed.
Second application, May 24.	.....do	Bordeaux mixture only (2-2-50). Not drenched.	Do.
Third application, June 26.	.....do	.....do	Do.
Fourth application, July 26-27.	.....do	.....do	Do.

Plat V (demonstration) received four applications in all, the Vermorel nozzle being used. The effort was made to spray thoroughly, but none of the trees was drenched. Plat VI (one-spray method) was thoroughly drenched, using Seneca nozzles, applying an average of 11 gallons per tree. This plat received three subsequent applications of Bordeaux mixture only, as shown in the schedule, to protect the fruit from possible infection by bitter rot. Plat VIII was left unsprayed throughout the season for purposes of comparison.

The first application, on April 27, was given just after most of the petals had fallen, and conditions were favorable for the work except that showers interrupted the spraying for about one hour. At the time of the second application, May 24, the weather was showery, but spraying was finished without serious interruption. The third application, on June 26, was interrupted near the close of the work by rain, while the fourth application, on July 26, was made under very favorable conditions, the weather being clear and dry. Comparatively little bitter rot developed during the season, even on the unsprayed plat. A heavy hail, however, which occurred during late June, badly injured the fruit and foliage. It was noticed that the hail injury to the fruit resulted in a much greater proportion of codling-moth larvæ entering on the side, and this fact must be taken into account in the consideration of the results.

Table IX gives the total wormy fruit and fruit free from codling-moth injury for the entire season for the eight count trees of each plat, the numbers of the trees in the figure agreeing with those in the table.

TABLE IX.—*Number of sound and wormy apples for each tree from one-spray, demonstration, and unsprayed plats. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	90	115	68	191	173	49	54	87	827	....
Sound	712	1,344	651	2,224	1,859	1,259	2,958	2,243	13,250	....
Total	802	1,459	719	2,415	2,032	1,308	3,012	2,330	14,077	....
Per cent sound	88.78	92.12	90.55	92.10	91.49	96.26	98.21	96.27	....	94.13

PLAT VI. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	498	367	627	168	445	362	391	462	3,320	....
Sound	2,080	2,166	4,478	1,150	2,800	1,617	1,650	1,577	17,518	....
Total	2,578	2,533	5,105	1,318	3,245	1,979	2,041	2,039	20,838	....
Per cent sound	80.30	85.52	87.72	87.26	86.29	81.71	80.90	77.35	....	84.07

PLAT VIII. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	1,165	1,593	545	560	1,641	1,444	1,089	1,001	9,038	....
Sound	2,258	2,089	271	456	1,470	1,544	904	1,206	10,198	....
Total	3,423	3,682	816	1,016	3,111	2,988	1,993	2,207	19,236	....
Per cent sound	65.97	56.79	33.22	44.89	47.90	51.68	45.31	54.65	....	53.02

Plat V, which received the demonstration treatment, gave 94.13 per cent fruit free from codling-moth injury, as against 84.07 per cent fruit free from this insect on the one-spray plat, a difference in favor of the demonstration treatment of 10.06 per cent. The check or unsprayed plat (VIII) shows 53.02 per cent fruit free from codling-moth injury, and there is thus a gain in sound fruit by the demonstration treatment of 41.11 per cent and by the one-spray method again of 31.05 per cent of sound fruit. As will be seen from the foregoing table, there were counted in Plats V, VI, and VIII, respectively, 14,077, 20,838, and 19,236 apples, a total for all plats of 54,151. Undoubtedly the results from the one-spray plat are less favorable than would have been the case had there been no hail. The injured places on the sides of the fruit permitted ready entrance of the larvæ, as indicated on all plats by the relatively high percentage of larvæ which entered the fruit on the side. This condition is shown in Table X, which gives the places of entrance of the fruit for each tree of each plat for the total larvæ of the two broods throughout the season.

TABLE X.—*Places of entrance of fruit by total larvæ for each tree of each plat. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

Total number of larvæ and places of entrance of fruit for each tree, first and second broods combined.									Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
Places of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.			
First and second broods:											
Calyx	8	6	5	13	15	2	4	11	64	7.73	....
Side	76	105	59	159	148	46	46	68	707	85.49	....
Stem	6	4	4	19	10	1	4	8	56	6.78	....
Total	90	115	68	191	173	49	54	87	827	100.00	827

PLAT VI. ONE SPRAY.

First and second broods:											
Calyx	35	12	26	7	12	23	17	19	151	4.55	....
Side	443	331	567	150	407	319	344	415	2,976	89.64	....
Stem	20	24	34	11	26	20	30	28	193	5.81	....
Total	498	367	627	168	445	362	391	462	3,220	100.00	3,220

PLAT VIII. UNSPRAYED.

First and second broods:											
Calyx	527	888	320	258	878	677	512	493	4,553	50.38	....
Side	483	508	158	231	561	620	439	429	3,429	37.94	....
Stem	155	197	67	71	202	147	138	79	1,056	11.68	....
Total	1,165	1,593	545	560	1,641	1,444	1,089	1,001	9,038	100.00	9,038

On the demonstration plat there was a total of 827 larvæ, with 3,220 for the one-spray plat and 9,038 on the unsprayed block. The notably less number on the demonstration plat is probably due to the destruction, from later sprayings, of larvæ entering at the side, which tendency, as stated, became very marked after the injury to the fruit by hail.

THE PLUM CURCULIO.

The effect of the treatments in the W. S. Ballard orchard in controlling the plum curculio on Plats V, VI, and VIII is shown in Table XI. Egg and feeding punctures are combined in the table under "No. punctures."

TABLE XI.—*Injury by plum curculio for entire season, Plats V, VI, and VIII. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

Number of punctured and sound apples, etc., per tree in each plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of fruit free from injury.
No. punctures	157	275	163	524	668	162	395	328	2,672	....
No. fruit punctured	115	187	103	345	463	114	267	252	1,846	....
No. sound fruit	687	1,272	616	2,070	1,569	1,194	2,747	2,076	12,231	....
No. fruit	802	1,459	719	2,415	2,032	1,308	3,014	2,328	14,077	....
Per cent free from injury	85.66	87.18	85.67	85.71	77.21	91.28	91.14	89.17	....	86.89

PLAT VI. ONE SPRAY.

No. punctures	1,510	1,290	2,143	360	1,095	647	775	823	8,644	....
No. fruit punctured	961	730	1,347	238	719	405	521	511	5,432	....
No. sound fruit	1,617	1,803	3,758	1,080	2,526	1,574	1,520	1,528	15,406	....
No. fruit	2,578	2,533	5,105	1,318	3,245	1,979	2,041	2,039	20,838	....
Per cent free from injury	62.72	71.17	73.61	81.94	77.84	79.53	74.96	74.93	....	73.93

PLAT VIII. UNSPRAYED.

No. punctures	2,746	2,571	705	962	2,490	1,939	1,865	2,300	15,578	....
No. fruit punctured	1,255	1,571	437	531	1,415	1,193	1,098	1,285	8,785	....
No. sound fruit	2,168	2,111	379	485	1,696	1,795	882	806	10,322	....
No. fruit	3,423	3,682	816	1,016	3,111	2,988	1,980	2,091	19,107	....
Per cent free from injury	63.30	57.33	57.33	46.44	47.73	60.00	44.54	38.54	....	54.02

The percentage of fruit uninjured by the curculio in the demonstration block, 86.89 per cent, shows a gain over that of the one-spray plat, 73.93 per cent, of 12.96 per cent, and the gain in percentage of uninjured fruit on the demonstration over the unsprayed plat is 32.87.

ORCHARD OF STRATHMORE ORCHARD COMPANY.

The orchard of the Strathmore Orchard Company is located near Mount Jackson in the Shenandoah Valley of Virginia. The size of the trees and general appearance of the orchard are indicated in Plate XI, figure 1. The location of the trees under experiment with respect to the rest of the orchard is shown in figure 36. All trees not in the experiment were sprayed by the owners. The treatments given and dates of application are stated in Table XII.

TABLE XII.—*Dates of applications for codling moth and plum curculio, one-spray method. Mount Jackson, Va., 1909.*

Dates of application.	Plat XIII. (Demonstration.)	Plat XV. (One-spray method.)	Plat XVII. (Unsprayed.)
First application, May 6–7 (after falling of petals).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (1–1–50). Pressure 120 to 140 pounds. 4.7 gallons per tree.	Drenched with arsenate of lead, 2 pounds to 50 gallons water. Pressure 175 pounds. Seneca nozzles. 8.1 gallons per tree.	Unsprayed.
Second application, May 28–29.	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (2–2–50).	Bordeaux mixture only (2–2–50). Not drenched.	Do.
Third application, July 8–9.	.....do..........................	.....do..........................	Do.

FIG. 1.—VIEW IN ORCHARD OF THE STRATHMORE ORCHARD COMPANY, NEAR MOUNT JACKSON, VA. (ORIGINAL.)

FIG. 2.—VIEW IN THE E. H. HOUSE ORCHARD, NEAR SAUGATUCK, MICH. (ORIGINAL.)

The demonstration plat (XIII) received in all three treatments of a combined Bordeaux mixture and arsenate of lead spray. Plat XV (one-spray method) received only one arsenate of lead treatment just after the falling of the petals, but two additional applications of Bordeaux mixture were given to protect the fruit and foliage from fungous diseases. Plat XVII was left unsprayed throughout. The Ben Davis variety of apple was used entirely in the experiments.

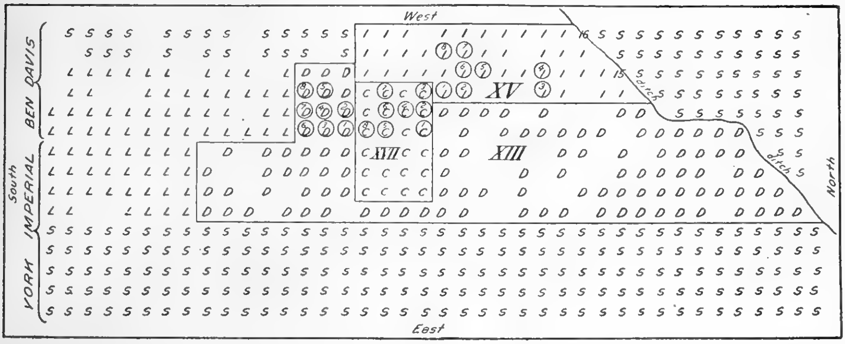

FIG. 36.—Diagram showing arrangement of plats and trees in the orchard of the Strathmore Orchard Co., near Mount Jackson, Va. Trees marked *S* sprayed by the owner; trees marked *L* used for experiments with lime-sulphur wash. Circles indicate count trees, the numbers agreeing with those in the tables. (Original.)

THE CODLING MOTH.

The results of the respective treatments in the control of the codling moth are shown in Table XIII.

TABLE XIII.—*Number of sound and wormy apples for each tree from one-spray, demonstration, and unsprayed plats. Mount Jackson, Va., 1909.*

PLAT XIII. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
Wormy	260	136	155	83	173	168	119	150	1,184	....
Sound	1,666	1,172	3,311	625	1,494	3,618	944	2,278	15,108	....
Total	1,866	1,308	3,466	708	1,667	3,786	1,063	2,428	16,292	....
Per cent sound	89.29	89.61	95.53	88.28	89.69	95.57	88.81	93.83	....	92.74

PLAT XV. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
Wormy	250	253	86	186	250	219	122	257	1,623	....
Sound	3,577	3,404	589	730	1,429	3,261	847	4,042	17,879	....
Total	3,827	3,657	675	916	1,679	3,480	969	4,299	19,502	....
Per cent sound	93.49	93.09	87.26	79.70	85.12	93.71	87.41	94.03	....	91.68

PLAT XVII. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
Wormy	1,913	1,425	865	983	1,538	1,792	2,027	1,247	11,790	....
Sound	2,013	1,684	965	524	1,651	2,361	3,094	1,548	13,840	....
Total	3,926	3,109	1,830	1,507	3,189	4,153	5,121	2,795	25,630	....
Per cent sound	51.23	54.17	52.19	34.78	51.78	56.86	60.42	55.42	....	54.00

As will be noted, the difference in results between the demonstration and one-spray plats is quite small, namely, 1.06 per cent in favor of the former. The unsprayed trees show 54 per cent of sound fruit, and there is thus a gain on the demonstration plat of 38.74 and on the one-spray plat of 37.68 per cent of sound fruit. A total of 61,424 apples was examined from Plats XIII, XV, and XVII, respectively, as follows, 16,292, 19,502, and 25,630.

The influence of the treatments on the places of entrance of fruit by the larvæ of the first and second broods combined is shown in Table XIV.

TABLE XIV.—*Places of entrance of fruit by total larvæ for each tree of each plat. Mount Jackson, Va., 1909.*

PLAT XIII. DEMONSTRATION.

Places of entrance.	Total number of larvæ and places of entrance of fruit for each tree, first and second broods combined. Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	32	14	15	16	20	26	15	24	162	13.68	....
Side	154	111	122	58	136	125	92	116	914	77.20	....
Stem	14	11	18	9	17	17	12	10	108	9.12	....
Total	200	136	155	83	173	168	119	150	1,184	100.00	1,184

PLAT XV. ONE SPRAY.

Places of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages.	Total number of larvæ.
First and second broods:											
Calyx	13	32	6	16	25	19	18	17	146	8.99	....
Side	190	193	74	143	173	183	91	214	1,261	77.70	....
Stem	47	28	6	27	52	17	13	26	216	13.31	....
Total	250	253	86	186	250	219	122	257	1,623	100.00	1,623

PLAT XVII. UNSPRAYED.

Places of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages.	Total number of larvæ.
First and second broods:											
Calyx	1,466	1,063	699	762	1,232	1,377	1,584	969	9,152	77.62	....
Side	332	265	119	141	203	295	353	209	1,917	16.26	....
Stem	115	97	47	80	103	120	90	69	721	6.12	....
Total	1,913	1,425	865	983	1,538	1,792	2,027	1,247	11,790	100.00	11,790

The demonstration plat shows 13.68 per cent of total larvæ entering at calyx end as compared with 8.99 per cent on the one-spray plat, the percentage entering on the sides being practically the same in both plats. The demonstration plat, however, shows a reduction in total number of larvæ, having 1,184 larvæ as against 1,623 for the one-spray plat and 11,790 for the untreated trees.

THE PLUM CURCULIO.

The plum curculio proved to be unusually destructive in the Strathmore orchard, which had not been plowed for at least two years and had grown up in grass and sod. The results of the respective treatments in the control of this insect are shown in Table XV, and as will be noted the percentage of fruit free from curculio injury is in all cases comparatively low. Nevertheless the one-spray treatment shows a gain of 17.08 per cent of fruit free from injury over the demonstration treatment, and a gain of 30.67 per cent of fruit free from injury over the unsprayed trees. The location of the trees in the respective plats does not indicate a more favorable place as regards liability to curculio injury for the one-spray block and the notably higher benefit of the single treatment in the control of the curculio on this plat is not understood.

TABLE XV.—*Injury by the plum curculio for entire season, plats XIII, X V, and X VII. Mount Jackson, Va., 1909.*

	Number of punctured and sound apples, etc., per tree in each plat.								Total for plat.	Total per cent fruit free from injury.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.		
PLAT XIII. DEMONSTRATION.										
No. punctures	2,961	2,391	3,067	932	3,013	4,040	1,486	2,869	20,759	....
No. fruit punctured	1,367	755	1,631	441	1,257	2,197	612	1,382	9,642	....
No. sound fruit	499	553	1,835	267	410	1,589	451	1,047	6,651	....
No. fruit	1,866	1,308	3,466	708	1,667	3,786	1,063	2,429	16,293	....
Per cent free from injury	26.79	42.27	52.94	33.71	24.58	41.97	42.42	43.10	....	40.82
PLAT XV. ONE SPRAY.										
No. punctures	2,782	1,800	633	1,032	1,449	2,159	987	3,153	13,995	....
No. fruit punctured	1,507	1,788	303	494	754	1,212	447	1,735	8,240	....
No. sound fruit	2,320	1,869	372	495	925	2,268	522	2,564	11,335	....
No. fruit	3,827	3,657	675	989	1,679	3,480	969	4,299	19,575	....
Per cent free from injury	60.62	51.10	55.11	50.15	55.09	65.17	53.86	59.64	....	57.90
PLAT XVIII. UNSPRAYED.										
No. punctures	7,336	4,497	2,212	2,888	5,030	6,122	8,779	4,904	41,768	....
No. fruit punctured	3,186	2,226	1,079	1,226	2,399	2,823	3,611	2,107	18,657	....
No. sound fruit	740	883	761	282	790	1,330	1,510	688	6,984	....
No. fruit	3,926	3,109	1,840	1,508	3,189	4,153	5,121	2,795	25,641	....
Per cent free from injury	18.84	28.40	41.35	18.61	24.77	32.04	29.46	24.61	....	27.23

EXPERIMENTS IN MICHIGAN.

The experiments in Michigan were carried out in the vicinity of Saugatuck, in the orchard of Mr. E. H. House. The location of the plats in the orchard and of the count trees in the respective plats is shown in figure 37. The size of the trees is illustrated in Plate XI, figure 2. This orchard included trees of the Wagener, Ben Davis, and Baldwin varieties, and an equal number of trees of each variety was used for counts in the respective plats. As in the work elsewhere, all drop-fruit during the season, as well as that from the trees at picking time, was taken into account and classified as to injury or otherwise. Also the work of the two broods of the codling moth was carefully separated by removing from the trees at the period of maximum maturation of the first-brood larvæ all fruit injured by the first brood, thus eliminating entirely from later counts first-brood work. The infested apples, however, were placed on the ground under the respective trees, so that development of second-brood larvæ would be in no wise interfered with.

The treatments given and dates of application are indicated in Table XVI.

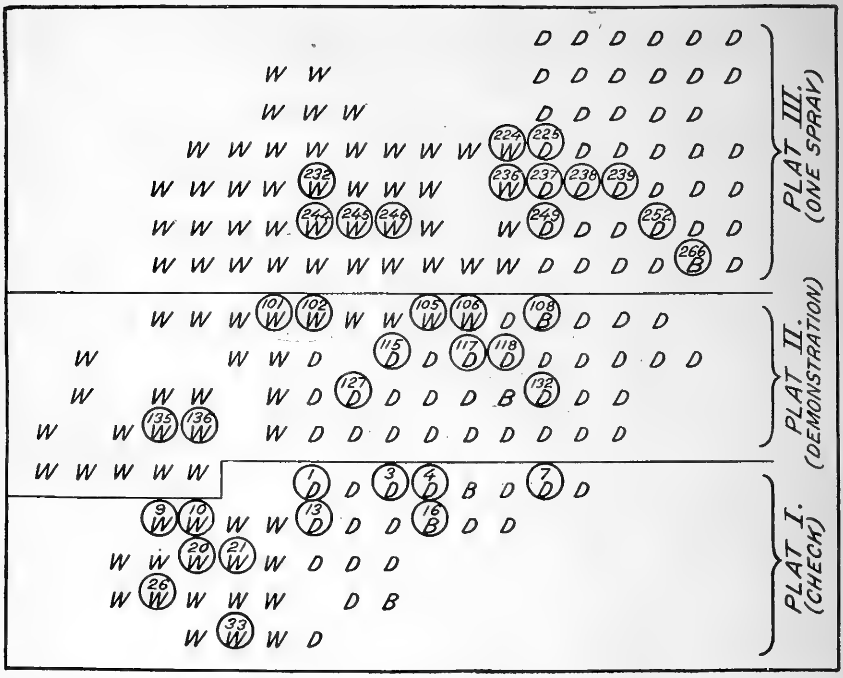

FIG. 37.—Diagram illustrating arrangement of plats and position of trees in the E. H. House orchard, near Saugatuck, Mich.: *D*, Ben Davis; *B*, Baldwin; *W*, Wagener. Count trees are indicated by circles, the numbers agreeing with those in the tables. (Original.)

TABLE XVI.—*Dates of applications for the codling moth and plum curculio, one-spray method. Saugatuck, Mich., 1909.*

Dates of applications.	Plat I. (Unsprayed.)	Plat II. (Demonstration.)	Plat III. (One-spray method.)
First application (before blossoms opened), May 20-21.	Unsprayed....	Not drenched. Vermorel nozzles. Mist spray. Bordeaux mixture (4-4-50).	Drenched. Bordeaux nozzles. Coarse spray. Bordeaux mixture (4-4-50).
Second application, June 3-9, after falling of petals.	.....do.........	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (4-4-50). Pressure, 125 pounds.	Drenched. Bordeaux nozzles. Coarse spray. Arsenate of lead, 1 pound to 50 gallons water. Pressure, 175 to 200 pounds.
Third application, June 21-22.	.....do.........	.....do......................	Bordeaux mixture only (4-4-50). June 10-11 and again June 21-22.
Fourth application, August 7-9.	.....do.........	.....do......................	Bordeaux mixture only (4-4-50).

Plat I was left unsprayed for purposes of comparison. Plat II (demonstration block) received four applications in all, the first before blooming but after cluster buds had opened, to protect the fruit from apple scab, which during some seasons in the lake region is very troublesome. Plat III (one-spray block) received the first scab treatment of Bordeaux mixture only and an additional treatment with arsenate of lead only at the rate of 1 pound to 50 gallons water immediately after the falling of the petals. This treatment was immediately followed by an application of Bordeaux mixture to prevent scab infection, as it was considered unsafe to apply the fungicide so excessively as the one-spray method required in the use of the arsenical. Plat III received two subsequent applications of Bordeaux mixture only, as shown in the schedule of applications, to further insure freedom from apple scab.

THE CODLING MOTH.

The percentages of wormy and sound fruit for the respective plats for the season are shown in Table XVII, and the numbers of trees in the table agree with those in the diagram of the orchard (fig. 37.)

TABLE XVII.—*Sound and wormy fruit from unsprayed, demonstration, and one-spray plats. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.
Wormy	663	752	605	166	946	1,207	416
Sound	3,996	5,033	2,947	1,340	1,805	2,676	2,213
Total	4,659	5,785	3,552	1,506	2,751	3,883	2,629
Per cent sound	85.76	87.00	82.96	88.97	65.61	68.91	84.17

Condition of fruit.	Tree 16.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	Total per cent sound.
Wormy	889	651	404	1,041	669	8,409	....
Sound	1,926	2,632	1,276	2,321	1,301	29,466	....
Total	2,815	3,283	1,680	3,362	1,970	37,875	....
Per cent sound	68.14	80.17	75.95	69.03	66.03	....	77.79

PLAT II. DEMONSTRATION.

Condition of fruit.	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.
Wormy	120	122	48	75	96	72	15
Sound	1,505	1,643	2,112	1,775	5,623	3,950	5,781
Total	1,625	1,765	2,160	1,850	5,719	4,022	5,796
Per cent sound	92.61	93.08	97.77	95.94	98.32	98.20	99.74

TABLE XVII.—*Sound and wormy fruit from unsprayed, demonstration, and one-spray plats. Saugatuck, Mich., 1909*—Continued.

PLAT II. DEMONSTRATION—Continued.

Condition of fruit.	Tree 118.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	Total per cent sound.
Wormy	25	91	13	245	76	998	....
Sound	5,188	4,336	4,285	3,978	1,644	41,820	....
Total	5,213	4,427	4,298	4,223	1,720	42,818	....
Per cent sound	99.52	97.94	99.69	94.19	95.58	....	97.66

PLAT III. ONE SPRAY.

Condition of fruit.	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.
Wormy	500	103	396	343	118	41	62
Sound	3,113	4,602	3,061	2,753	2,779	3,510	3,062
Total	3,613	4,705	3,457	3,096	2,897	3,551	3,124
Per cent sound	86.16	97.95	88.54	88.92	95.92	98.84	98.01

Condition of fruit.	Tree 244.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	Total per cent sound.
Wormy	452	340	165	62	46	110	2,738	....
Sound	4,107	4,001	2,743	3,381	1,092	1,925	40,129	....
Total	4,559	4,341	2,908	3,443	1,138	2,035	42,867	....
Per cent sound	90.08	92.16	94.32	98.19	95.95	94.59	....	93.61

It will be noted from the foregoing table that the unsprayed trees (Plat I) show 77.79 per cent of fruit free from the codling moth, which is a lighter injury than usual for that section. Band records of the larvæ covering the season 1909, taken from trees in another orchard, show that only 13 per cent of the first-brood larvæ transformed to moths, and hence the second brood was comparatively light. The demonstration plat shows an increase of sound fruit over the one-spray method of 4.05 per cent and over the unsprayed plat of 19.87 per cent. The apples counted on the respective plats were 37,875, 42,818, and 42,867, giving a total of 123,560.

The effect of the treatments on the places of entrance of fruit by larvæ of the first and second broods is shown in Table XVIII.

TABLE XVIII.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Total number of larvæ and places of entrance of fruit for each tree by broods.

Places of entrance.	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.	Tree 16.
First brood:								
Calyx	133	206	172	65	316	257	168	214
Side	39	24	25	10	28	28	17	40
Stem	5	8	0	0	7	6	4	5
Total	177	238	197	75	351	291	189	259
Second brood:								
Calyx	277	272	274	51	279	316	140	357
Side	213	249	155	39	319	360	87	306
Stem	16	9	15	2	19	30	7	11
Total	506	530	444	92	617	706	234	674

Places of entrance.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ of first and second broods.
First brood:							
Calyx	176	129	442	266	2,544	85.20	....
Side	17	21	68	59	376	12.59	....
Stem	4	5	13	9	66	2.21	....
Total	197	155	523	334	2,986	....	....
Second brood:							
Calyx	208	105	290	183	2,752	50.45	....
Side	240	151	231	181	2,531	46.40	....
Stem	18	6	21	18	172	3.15	....
Total	466	262	542	382	5,455	....	8,441

PLAT II. DEMONSTRATION.

Total number of larvæ and places of entrance of fruit for each tree by broods.

Places of entrance.	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.	Tree 118.
First brood:								
Calyx	....	....	1	....	5	10	2	2
Side	9	12	14	12	8	5	5	4
Stem	....	1	....	....	1	....	....	....
Total	9	13	15	12	14	15	7	6
Second brood:								
Calyx	....	....	....	....	2	....	....	1
Side	146	155	41	81	95	73	8	19
Stem	....	....	....	....	....	....	....	....
Total	146	155	41	81	97	73	8	20

TABLE XVIII.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909*—Continued.

PLAT II. DEMONSTRATION—Continued.

Places of entrance.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ of first and second broods.
First brood:							
Calyx	8	1	....	2	31	20.95	....
Side	7	1	27	11	115	77.70	....
Stem	....	....	....	....	2	1.35	....
Total	15	2	27	13	148	....	....
Second brood:							
Calyx	1	....	1	1	6	.52	....
Side	95	11	320	93	1,137	99.30	....
Stem	1	....	1	....	2	.18	....
Total	97	11	322	94	1,145	....	1,293

PLAT III. ONE SPRAY.

Total number of larvæ and places of entrance of fruit for each tree by broods.

Places of entrance.	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.	Tree 244.
First brood								
Calyx	5	3	....	2	....	2	1	3
Side	86	6	15	24	7	5	2	31
Stem	2	1	....	1	....	....	....	....
Total	93	10	15	27	7	7	3	34
Second brood:								
Calyx	4	1	6	4	1	1	1	4
Side	356	141	416	370	161	43	75	492
Stem	9	....	....	4	....	....	....	2
Total	369	142	422	378	162	44	76	498

Places of entrance.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ of first and second, broods.
First brood:								
Calyx	2	1	1	....	....	20	7.38	....
Side	40	13	6	1	9	245	90.41	....
Stem	....	2	....	....	....	6	2.21	....
Total	42	16	7	1	9	271	....	....
Second brood:								
Calyx	9	....	4	....	2	37	1.30	....
Side	297	176	67	52	131	2,777	97.54	....
Stem	13	4	....	....	1	33	1.16	....
Total	319	180	71	52	134	2,847	....	3,118

A study of the percentages of larvæ of the respective broods entering the calyx, side, and stem ends of the fruit for each plat, taken in connection with the treatments given, presents some points of interest.

On all plats a greater percentage of larvæ of the first brood entered at the calyx than was true of larvæ of the second brood. Thus, on the unsprayed plat (I), 85.20 per cent of the first-brood larvæ entered at calyx as against 50.45 per cent of second-brood larvæ. On Plat II (demonstration) 20.95 per cent of first-brood larvæ entered at calyx end as compared with 0.52 per cent of second-brood larvæ, while on Plat III (one spray) 7.38 per cent of first-brood larvæ entered at calyx and 1.30 per cent of second-brood larvæ entered at this place. In comparing Plats II and III a reduction of first-brood larvæ entering at calyx is noted in favor of the one-spray method of 13.57 per cent—7.38 per cent as against 20.95 per cent.

In the case of second-brood calyx-entering larvæ, however, the difference is in favor of the demonstration plat (II), though in both plats the percentages of total larvæ entering the fruit at calyx is very small. Many interesting deductions may be drawn from tables of this character, which, however, are plainly evident to the reader.

Attention, nevertheless, should be called to the ratio of increase of larvæ between the first and second broods. On Plat I (unsprayed), for every larva of the first brood there were 1.82 second-brood larvæ, whereas on Plat II (demonstration) and Plat III (one spray) for each larva of the first brood there were 7.7 and 10.5, respectively, of the second brood.

Similar comparison may also be made from the data from Arkansas. Thus, on the unsprayed plat (V) for each first-brood larva there were 4.8 second-brood larvæ. On Plat III (one spray) for each larva of the first brood there were 105.6 larvæ of the second brood. Plat I (one-spray method) shows for each first-brood larva 121.5 second-brood larvæ.

THE PLUM CURCULIO.

The effects of the applications of sprays on the plum curculio in the E. H. House orchard are shown in Table XIX.

TABLE XIX.—*Injury by the plum curculio for entire season, Plats I, II, and III. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Number of punctured and sound apples, etc., per tree in each plat.

	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.
No. punctures	1,452	422	506	505	1,078	756	141
No. fruit punctured	866	214	220	241	480	372	56
No. sound fruit	3,793	5,571	3,332	1,265	2,271	3,511	2,573
No. fruit	4,659	5,785	3,552	1,506	2,751	3,883	2,629
Per cent free from injury	81.41	96.30	93.81	83.99	82.55	90.42	97.87

TABLE XIX.—*Injury by the plum curculio for entire season, Plats I, II, and III. Saugatuck, Mich, 1909*—Continued.

PLAT I. UNSPRAYED—Continued.

	Tree 16.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	Total. per cent fruit free from injury.
No. punctures	1,108	883	530	1,265	1,197	9,843	....
No. fruit punctured	454	426	329	644	462	4,764	....
No. sound fruit	2,361	2,857	1,351	2,718	1,508	33,111	....
No. fruit	2,815	3,283	1,680	3,362	1,970	37,875	....
Per cent free from injury	83.87	86.96	80.42	80.85	76.55	....	87.42

PLAT II. DEMONSTRATION.

Number of punctured and sound apples, etc., per tree in each plat.

	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.
No. punctures	24	37	32	128	169	12	102
No. fruit punctured	11	13	15	60	61	5	62
No. sound fruit	1,614	1,752	2,145	1,790	5,658	4,017	5,734
No. fruit	1,625	1,765	2,160	1,850	5,719	4,022	5,796
Per cent free from injury	99.38	99.26	99.31	96.76	98.93	99.88	98.93

	Tree 118.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	Total per cent fruit free from injury.
No. punctures	112	89	139	398	10	1,252	....
No. fruit punctured	32	50	58	153	3	523	....
No. sound fruit	5,181	4,377	4,240	4,070	1,717	42,295	....
No. fruit	5,213	4,427	4,298	4,223	1,720	42,818	....
Per cent free from injury	99.39	98.87	98.65	96.38	99.83	....	98.77

PLAT III. ONE SPRAY.

Number of punctured and sound apples, etc., per tree in each plat.

	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.
No. punctures	1,015	278	108	198	64	67	45
No. fruit punctured	374	117	35	85	30	33	19
No. sound fruit	3,239	4,588	3,422	3,011	2,867	3,518	3,105
No. fruit	3,613	4,705	3,457	3,096	2,897	3,551	3,124
Per cent free from injury	89.92	97.51	98.99	97.25	98.96	99.07	99.39

	Tree 244.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	Total per cent fruit free from injury.
No. punctures	228	255	238	194	42	143	2,875	....
No. fruit punctured	65	102	91	43	20	40	1,054	....
No. sound fruit	4,494	4,239	2,817	3,400	1,118	1,995	41,813	....
No. fruit	4,559	4,341	2,908	3,443	1,138	2,035	42,867	....
Per cent free from injury	98.57	97.65	96.87	98.75	98.24	98.03	....	97.54

The plum curculio, it will also be noted, was not especially destructive at Saugatuck, Mich., during the season of 1909, the unsprayed trees showing 87.42 per cent of fruit free from injury. Nevertheless the demonstration and one-spray plats show a fair benefit, but the difference in the amount of fruit free from injury between these two plats, namely, 1.23 per cent, is not important.

SUMMARY STATEMENT OF RESULTS.

For the purpose of more ready comparison, the percentages of fruit free from codling-moth and plum-curculio injury on the one-spray, demonstration, and unsprayed plats, from the several localities, are tabulated in Table XX. The average percentage of fruit free from these insects for the four orchards gives for the one-spray method 91.46 per cent as against 96.57 per cent for the demonstration treatment, a gain in favor of the latter of 5.11 per cent. Comparing the final average of percentage of fruit free from the plum curculio, there is seen to be a gain in favor of the demonstration treatment of 6.27 per cent.

TABLE XX.—*Percentages of fruit free from injury by the codling moth and plum curculio on one-spray, demonstration, and unsprayed plats in Arkansas, Virginia, and Michigan, in 1909.*

Locality.	Codling moth.			Plum curculio.		
	One spray.	Demonstration.	Unsprayed.	One spray.	Demonstration.	Unsprayed.
Siloam Springs, Ark	92.76	98.12	66.74	86.34	82.88	8.85
Crozet, Va	84.07	94.13	53.02	73.93	86.89	54.02
Mount Jackson, Va	91.68	92.74	54.00	57.90	40.82	27.23
Saugatuck, Mich	93.61	97.66	77.79	97.54	98.77	87.42
Average of four localities	91.46	96.57	65.14	77.10	83.37	49.17

Table XXI presents in comparison the effect of treatments for the four orchards, on the places of entrance of the fruit by the larvæ. The figures given are percentages of total larvæ for the season entering fruits at the calyx, side, and stem, respectively, for the one-spray, demonstration, and unsprayed plats. The average for the four orchards is interesting, especially in respect to calyx entrance, which on the one-spray plat is 7.67 per cent and on the demonstration plat is 15.29 per cent, a lessening of calyx entrances of 7.62 per cent by the drenching-spray method. The proportion of larvæ entering fruit at the calyx end under normal conditions is evidently about that shown for the unsprayed plats, the final average being 68.17 per cent, including both first and second broods.

TABLE XXI.—*Percentages of larvæ entering fruit at the calyx, side, and stem, respectively, for the one-spray, demonstration, and unsprayed plats in Arkansas, Virginia, and Michigan, in 1909.*

Locality.	First and second broods of the codling moth combined.								
	Calyx.			Side.			Stem.		
	One spray.	Demonstration.	Unsprayed.	One spray.	Demonstration.	Unsprayed.	One spray.	Demonstration.	Unsprayed.
Siloam Springs, Ark.	15.96	54.81	79.73	75.38	41.93	15.93	8.66	3.26	4.34
Crozet, Va.	4.55	7.73	50.38	89.64	85.49	37.94	5.81	6.78	11.68
Mount Jackson, Va.	8.99	13.68	77.62	77.70	77.20	16.26	13.31	9.12	6.12
Saugatuck, Mich.	1.83	2.86	62.74	96.92	96.83	34.44	1.25	0.31	2.82
Average	7.67	15.29	68.17	85.89	79.91	25.50	6.44	4.80	6.33

CONCLUSIONS.

From the data presented, covering one season's work in three States, it appears that very satisfactory results may be obtained by the one-spray method, in so far as the control of the codling moth and plum curculio is concerned, although further experimentation will be necessary before final conclusions can be reached. Sight must not be lost, however, of the fact of the necessity, under eastern conditions, of making applications of Bordeaux mixture or other fungicide for the control of fungous diseases; so that in effect the one-spray method under present practices can not be recommended to orchardists in regions where fungous troubles, such as apple scab, apple fruit blotch, bitter rot, and leaf-spot affections require treatment.

The results, however, show the great importance of very thorough spraying to fill the calyx cups with poison. Although the importance of accomplishing this has long been recognized by entomologists and fruit growers, it would appear that this work has not been done with sufficient thoroughness in the past, and eastern apple growers could certainly with great profit give more attention to thoroughness in the first spraying for the codling moth, immediately after the falling of the petals. The russeting of the fruit following such drenching applications of Bordeaux mixture, in which the arsenical has been generally applied, may doubtless be avoided by the substitution as a fungicide of dilute or self-boiled lime-sulphur wash, as shown to be feasible by Mr. W. M. Scott, of the Bureau of Plant Industry.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 80, Part VII (Revised).

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

BY

A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations,

AND

E. L. JENNE, E. W. SCOTT, AND R. W. BRAUCHER,

Engaged in Deciduous Fruit Insect Investigations.

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Deciduous Fruit Insect Investigations.

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THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

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INTRODUCTION.

The so-called one-spray method of spraying for the codling moth on apples consists essentially in making the application following the dropping of the petals so thorough that it will result in the practical extermination of the first brood of larvæ, subsequent treatments, therefore, becoming unnecessary. This method of spraying has come into considerable use in the Northwest following the investigations of Dr. E. D. Ball, in Utah, and Prof. A. L. Melander, in Washington, and its applicability for the control of the codling moth under eastern conditions has been strongly urged. The subject has already received attention at the hands of several eastern entomologists, notably Gossard, in Ohio, Sanderson, in New Hampshire, Felt, in New York, and Rumsey, in West Virginia. It is not within the scope of the present paper, which is in the nature of a preliminary report, to review the present status of the one-spray method. On the whole, however, it has appeared to the writers from a study of the experiments thus far reported as bearing directly upon the control of the codling moth, that most of these have been more or less inconclusive as not having fully met the conditions stated to be essential for successful one-spray work. The indispensable requisite is stated to be the placing of necessary poison in the inner calyx cup. By referring to figure 33 the structure of the calyx end of a young apple may be noted, namely, that there are two cavities, one above and one below the stamen bars or filaments. The observations of Doctor Ball led him to believe that the great majority of codling-moth larvæ in seeking entrance at the calyx end of the apple enter through the lower

calyx cup, and would thus mostly escape destruction unless the poison had been there placed. Other investigators have shown, notably the late Professor Slingerland, that codling-moth larvæ in the East feed in the outer calyx cup, and the results which have been obtained with mist sprays in the East during the past twenty-five years, filling mostly only the outer calyx cavity, have been much more favorable than could be expected were it the rule that feeding occurs principally in the inner cup. The stamen bars, as shown in the figure, form a dome or shield over the cavity below, and the poison is best forced

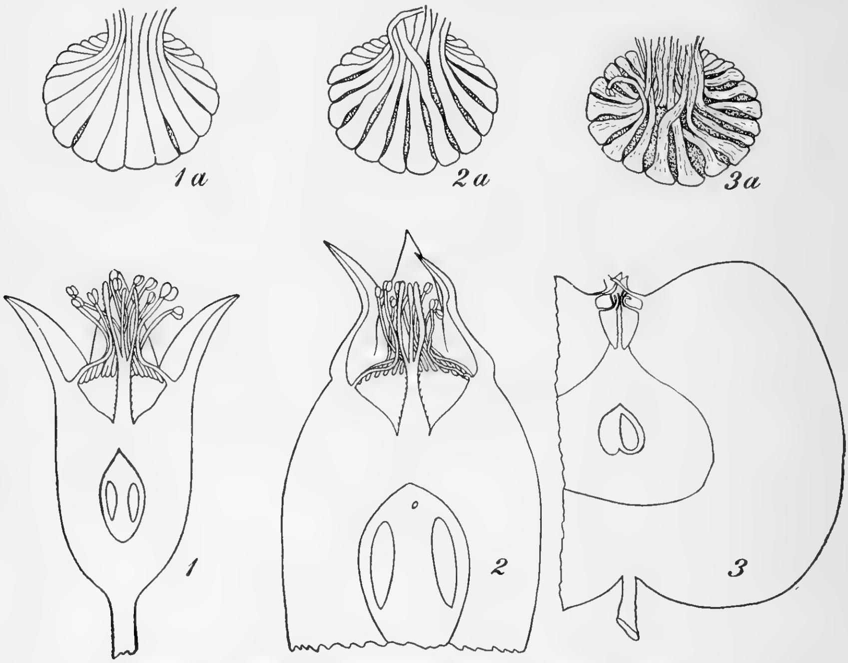

FIG. 33.—The condition of the calyx cup of the apple in relation to spraying for the codling moth: *Fig. 1.*—A calyx cup, five days after the petals fell, split open to show two cavities; *1a*, the roof of stamens as seen from above. *Fig. 2.*—A calyx cup two weeks after blossoming, showing the calyx lobes above; *2a*, the stamens from above to show spaces. *Fig. 3.*—The relation of the two cavities in a nearly grown apple; *3a*, stamens from above. (From Ball.)

through these bars by a coarse, forceful spray, as from a Bordeaux nozzle and with a pump pressure of from 175 to 200 or more pounds. It is also required that the work of spraying be done very thoroughly, the spray being directed from above into each and every fruit cluster. The use of an elbow or crook between the rod and nozzle to incline the nozzle at an angle of from 30 to 45 degrees with the spray rod permits of better directing the spray downward, and even in the case of small trees it is recommended to spray from a platform on the wagon. The employment of a coarse nozzle and a high pressure uses a large amount of spray before the trees are properly sprayed, literally drenching the trees.

This single treatment, as above described, made just after the falling of the petals, in the experience of Professor Melander has been sufficient to keep the codling moth under complete control. Doctor Ball, however, inclines to two early treatments, the second being given before the calyx lobes entirely close, as within ten days after the falling of the petals. At the time of this latter treatment the stamen bars have become more or less shriveled and more readily permit the entrance of the spray into the inner calyx cup. The two practices as recommended by Professors Ball and Melander do not differ in principle, however, and Doctor Ball's second treatment is in the nature of a supplementary one. In summing up his experiments, covering several years in Utah, Doctor Ball states his conclusions as follows:[a]

> The first early spray is the best, the second is nearly as good, and the third is of little value.
>
> Two early driving sprays will kill an average of 90 per cent of the first brood of worms.
>
> Sufficient poison is retained [in calyx cup] from the early sprayings to kill an average of 74 per cent of the second brood of worms.
>
> Two early sprayings correctly applied are worth from 6 to 16 times as much as three late ones.

Professor Melander says:[b]

> A single thorough spraying has afforded practically 100 per cent returns over hundreds and hundreds of acres of Washington orchards. The same benefit from the single spraying has also been abundantly attained in Colorado and Utah.

Aside from the particular question involved as to whether the one-spray method will sufficiently control the codling moth under eastern conditions, several other considerations must be taken into account.

In the arid valleys of the West, as in Utah, Washington, and Colorado, practically the only important insect enemy of the fruit of the apple is the codling moth, and fungous diseases are, on the whole, of but little importance. The use of fungicides is therefore not ordinarily necessary and there is thus to be controlled only the codling moth.

In the Mississippi Valley and Eastern States, however, and in central and eastern Canada, there are, in addition to the codling moth, the apple and plum curculios and the lesser apple worm, which in many sections are exceedingly injurious, the plum curculio in some parts being scarcely less in importance than the codling moth itself. Furthermore, the general prevalence of fungous diseases, such as the apple scab, apple fruit blotch, bitter rot, and leaf-spot affections, requires several fungicidal treatments during the season. Entomolo-

[a] Bul. 67, Bur. Ent., U. S. Dept. Agr., p. 75, 1907.

[b] Journal of Economic Entomology, vol. 2, p. 67, 1909.

gists and plant pathologists have by many experiments determined a schedule of spraying with a combined arsenical insecticide and a fungicide—Bordeaux mixture or lime-sulphur wash—which affords a large degree of protection from all of these troubles. To effect the control of insects other than the codling moth and the several fungous diseases mentioned requires several applications of sprays, and renders the one-spray method of questionable practical value where these several troubles exist. These differences in fruit-growing conditions between the West and East should be borne in mind in any consideration of the practicability of the one-spray method.

RESULTS OF EXPERIMENTS WITH THE ONE-SPRAY METHOD AS COMPARED WITH RESULTS FROM THE USUAL SCHEDULE OF APPLICATIONS.

During the season of 1909 the Bureau of Entomology carried out experiments to determine the relative value, in the control of the codling moth and plum curculio under eastern conditions, of the one-spray method in comparison with a schedule of applications requiring a total of from three to five treatments according to locality, representing practically the method of spraying considered best for the localities in question. The work was carried out in three States, namely, in Virginia, in Arkansas, and in Michigan, and included four orchards, thus representing a considerable range in climatic conditions. The field work in Arkansas was under the immediate direction of Mr. E. L. Jenne, assisted by Mr. F. W. Faurot; in Virginia the field operations were under the immediate charge of Mr. E. W. Scott, assisted by Mr. L. F. Pierce, of the Bureau of Plant Industry. Mr. R. W. Braucher was charged with the spraying operations in Michigan, and was assisted a part of the time by Mr. Walter Postiff. The work relating to the control of fungous diseases in each of the orchards was done in cooperation with Mr. W. M. Scott, of the Bureau of Plant Industry. In addition to obtaining data on the effects of the treatments on the codling moth and plum curculio, in Arkansas injury by the lesser apple worm was taken into account, which in that section is very troublesome.

EXPERIMENTS IN ARKANSAS.

The experiments in Arkansas were carried out in the orchard of Mrs. S. E. Jones in the vicinity of Siloam Springs. The entire orchard, consisting of 344 trees, was divided into five plats, as shown in the accompanying diagram (fig. 34.) Trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. The orchard, a general view of which is shown in Plate X,

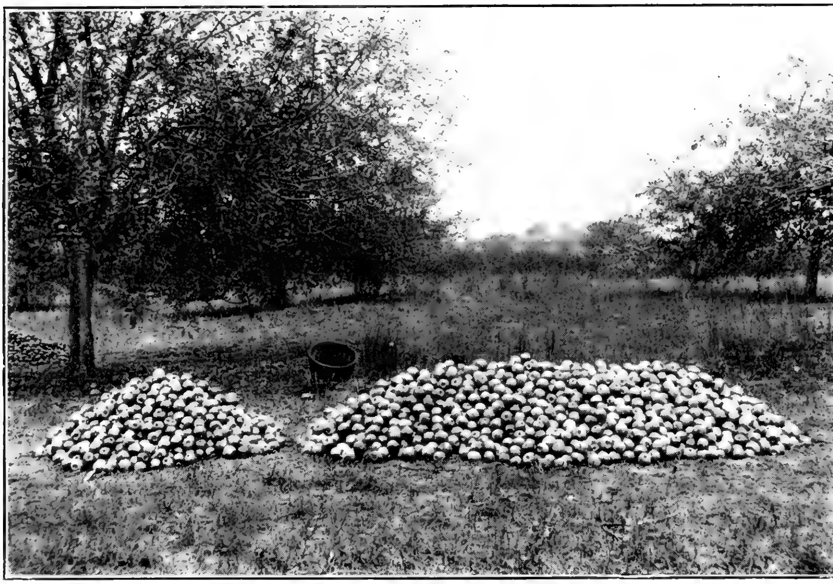

FIG. 1.—VIEW IN ORCHARD OF MRS. S. E. JONES, NEAR SILOAM SPRINGS, ARK. (ORIGINAL.)

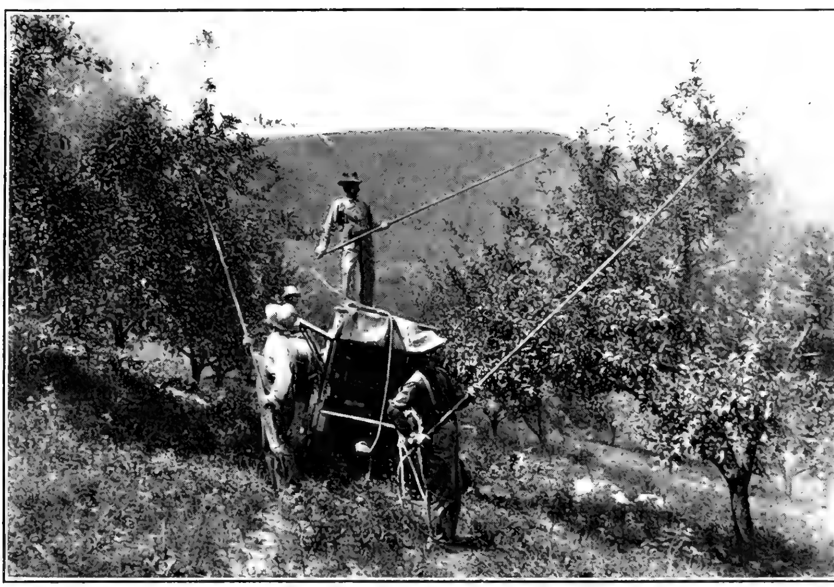

FIG. 2.—VIEW IN ORCHARD OF MR. W. S. BALLARD, NEAR CROZET, VA. (ORIGINAL.)

figure 1, is an isolated one and the location very favorable for the work in hand. Plat I included 7 rows, Plat II a single row, Plat III 3 rows, Plat IV 5 rows, and Plat V (the unsprayed plat) included 5 rows, this last plat being at one end of the orchard. The orchard

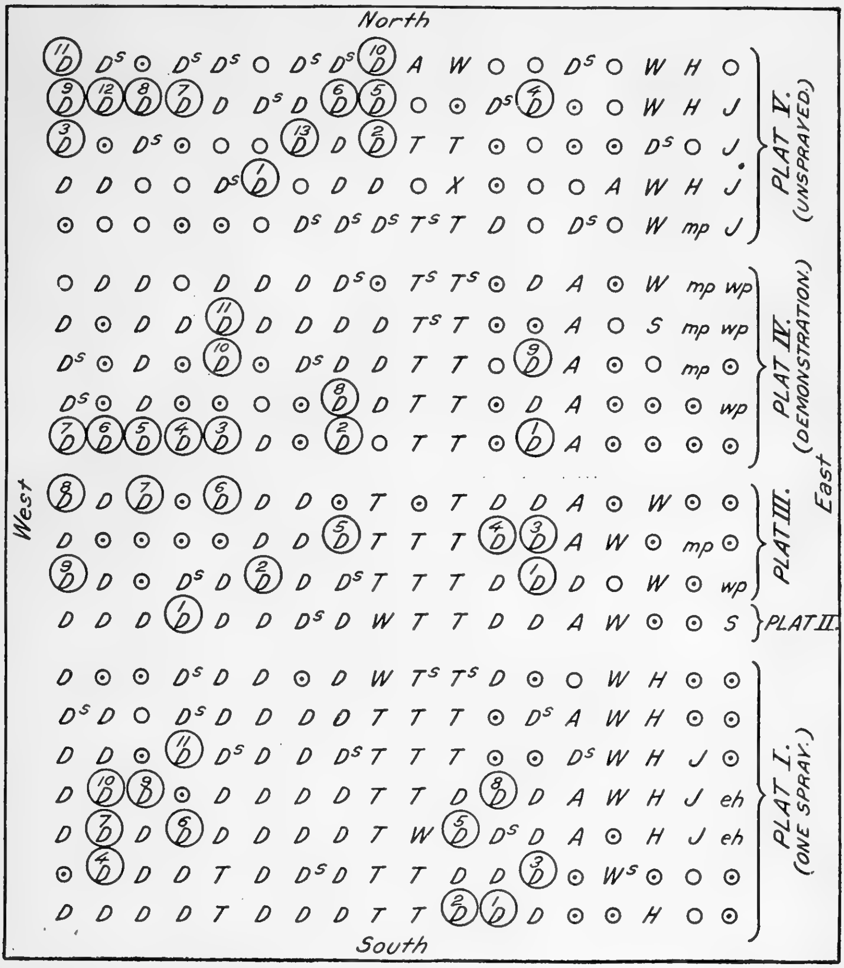

FIG. 34.—Diagram of the Mrs. S. E. Jones orchard, Siloam Springs, Ark., showing location of plats and trees used for making counts of fruit: *D*, Ben Davis variety; *A*, Arkansas Black; *T*, Mammoth Black Twig; *W*, Winesap; *J*, Jonathan; *mp*, Missouri Pippin; *wp*, White Winter Pearmain, etc. Trees of Ben Davis variety only were used for making counts of fruit. These are indicated for the respective plats by a circle, the numbers agreeing with the numbers of these trees in the tables. (Original.)

included a miscellaneous assortment of varieties, as shown by the legend under figure 34, but principally the Ben Davis, on which variety counts were made. The treatments to which the respective plats were subjected is shown in Table I.

TABLE I.—*Treatments and dates of applications of sprays for the codling moth and plum curculio. One-spray method. Siloam Springs, Ark., 1909.*

Dates of applications.	Plat I. (One-spray method.)	Plat II. (One-spray method.)
First application, April 24-25 (after falling of petals).	Drenched with arsenate of lead. 1 pound to 50 gallons of water. Bordeaux nozzles. 17 gallons per tree. 200 pounds pressure.	Drenched with arsenate of lead. 1 pound to 50 gallons Bordeaux mixture (3-3-50). Bordeaux nozzles. 17 gallons per tree. 200 pounds pressure.
Second application, May 25-26.	Bordeaux mixture only (4-4-50). Bordeaux nozzles.	Bordeaux mixture only (4-4-50). Bordeaux nozzles.
Third application, July 2.	.....do	Do.
Fourth application, July 22.	Unsprayed	Unsprayed.
Fifth application, August 10.	.....do	Do.

Dates of applications.	Plat III. (One-spray method.)	Plat IV. (Demonstration.)	Plat V. (Unsprayed.)
First application, April 24-25 (after falling of petals).	Drenched with arsenate of lead. 1 pound to 50 gallons of water. Vermorel nozzles. Mist spray. 8.3 gallons per tree. 200 pounds pressure.	Not drenched. Vermorel nozzles. Mist spray, arsenate of lead. 2 pounds to 50 gallons Bordeaux mixture (3-3-50). 11 gallons per tree. 200 pounds pressure.	Unsprayed.
Second application, May 25-26.	Bordeaux mixture only (4-4-50). Mist spray. Vermorel nozzles.	Bordeaux mixture (4-4-50) with 2 pounds arsenate of lead. Mist spray. Vermorel nozzles.	Do.
Third application, July 2.	.....do	Bordeaux mixture (4-4-50) with 2 pounds arsenate of lead. Mist spray. Vermorel nozzles.	Bordeaux mixture only (4-4-50).
Fourth application, July 22.	Unsprayed	.....do	Unsprayed.
Fifth application, August 10.	.....do	.....do	Do.

Plats I, II, and III received an arsenical treatment of 1 pound of arsenate of lead to 50 gallons of water immediately after the falling of the petals. Two subsequent applications of Bordeaux mixture only were made to protect the fruit from the apple blotch and bitter rot and one Bordeaux treatment was also given to the check plat (Plat V) for the same purpose, as these affections in this locality are exceedingly troublesome and otherwise would have interfered greatly with results. Plat IV, which received demonstration treatment, received five applications in all, as shown, of a combined spray of Bordeaux mixture and arsenate of lead, the latter being used at the rate of 2 pounds to 50 gallons of spray. On the demonstration plat the usual eddy chamber, or Vermorel nozzle, was used and while an effort was made to spray thoroughly according to usual recommendations in the East, the drenching of the trees was carefully avoided. Plat I, which received the one-spray treatment proper, was very thoroughly treated and required an average of 17 gallons per tree. The Bordeaux nozzle was used with a crook between the nozzle and spray rod and a pressure was maintained at about 200 pounds. Plat II received exactly the same treatment except that arsenate of lead was applied in dilute Bordeaux mixture to determine

to what extent russeting of the fruit might result from so liberal a use of the fungicide. The treatment for Plat III was identical with that for Plat I, except that Vermorel nozzles were used. It was desired to determine the comparative merits of a mist spray as against a coarse spray, and it will be noted that the quantity of liquids required per tree for the mist spray (Plat III) was somewhat less than one-half the amount necessary in the drenching work (Plat I).

The results presented include all of the drop fruit throughout the season and the fruit from the trees at picking time in the fall. All apples were carefully examined as to worminess from the codling moth and as to injury by the plum curculio and lesser apple worm. Fruit from Plats I and III was badly injured by the apple blotch, which can be accounted for only by the omission of Bordeaux mixture from the treatment given immediately after the falling of the petals. Fruit from Plat II, which had been thoroughly drenched with Bordeaux mixture using Bordeaux nozzles, was not noticeably more russeted than in the case of fruit from the demonstration plat and was free from apple blotch. Plat IV showed some infection from scab owing to the fact that it had not been sprayed with Bordeaux mixture before the blossoms opened.

THE CODLING MOTH.

In Table II are shown results of treatments of Plats I, III, IV, and V as to injury from the codling moth. Plat II is not here considered nor subsequently, as the point involved, namely, the effect on the fruit of a drenching spray of arsenate of lead and Bordeaux mixture after the falling of the petals, has already been indicated. There was not noticeably more russeting of the fruit on Plat II than on Plat IV which received the demonstration treatment.

TABLE II.—*Sound and wormy apples from one-spray, demonstration, and unsprayed plats. Siloam Springs, Ark., 1909.*

PLAT I. ONE SPRAY (BORDEAUX NOZZLES).

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	703	522	419	118	181	222	286	315
Sound	4,986	4,291	3,377	2,632	3,265	3,540	3,021	5,128
Total	5,689	4,813	3,796	2,750	3,446	3,762	3,307	5,443
Per cent sound	87.65	89.16	88.97	95.71	94.74	94.19	91.36	94.22

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	110	113	131			3,120	
Sound	3,489	2,539	3,764			40,032	
Total	3,599	2,652	3,895			43,152	
Per cent sound	96.95	95.71	96.69				92.76

TABLE II.—*Sound and wormy apples from one-spray, demonstration, and unsprayed plats. Siloam Springs, Ark., 1909*—Continued.

PLAT III. ONE SPRAY (VERMOREL NOZZLES).

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	397	298	286	431	321	247	231	200
Sound	4,352	3,187	2,458	2,221	1,920	3,323	2,650	1,792
Total	4,749	3,485	2,744	2,652	2,241	3,570	2,881	1,992
Per cent sound	91.65	91.45	89.58	83.79	85.73	93.09	91.99	89.96

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	234					2,645	
Sound	1,986					23,889	
Total	2,220					26,534	
Per cent sound	89.46						90.03

PLAT IV. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	36	41	93	16	22	23	57	57
Sound	3,500	1,849	4,983	1,649	3,123	1,642	2,439	3,115
Total	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172
Per cent sound	98.99	97.83	98.17	99.04	99.31	98.62	97.72	98.21

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	154	67	41			607	
Sound	4,637	1,890	3,017			31,844	
Total	4,791	1,957	3,058			32,451	
Per cent sound	96.79	96.58	98.66				98.12

PLAT V. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Wormy	795	679	217	716	450	823	697	287
Sound	1,765	1,004	778	822	756	1,678	2,124	869
Total	2,560	1,683	995	1,538	1,206	2,501	2,821	1,156
Per cent sound	68.95	59.66	78.20	53.45	62.68	67.10	75.30	75.18

Condition of fruit.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Total per cent sound.
Wormy	652	859	709	592	644	8,120	
Sound	1,671	1,399	1,010	1,016	1,416	16,308	
Total	2,323	2,258	1,719	1,608	2,060	24,428	
Per cent sound	71.94	61.18	58.76	63.19	68.74		66.74

Plat I, which received the one-spray treatment, shows an average of 92.76 per cent of fruit free from the codling moth, the percentages for individual trees ranging from 87.65 to 96.95. The total number

of apples counted from this plat was 43,152. Plat III received the drenching mist spray with Vermorel nozzle and shows for the individual trees a range in percentage of fruit free from the codling moth of 83.79 to 91.99, with an average for all trees of 90.03. There were 26,534 apples examined. Plat IV, which received the demonstration treatment of five applications, shows a total from the 11 trees of 98.12 per cent of fruit free from the codling moth, with a range for individual trees of 96.58 to 99.31 per cent, and the total number of apples counted was 32,451. Plat V (the unsprayed block) shows, for the 13 trees from which counts were made, 66.74 per cent of fruit free from the codling moth, the range being from 53.45 to 78.20 per cent, the total number of apples counted being 24,428. Demonstration plat, No. IV, shows an increase over the unsprayed trees of 31.38 per cent of uninjured fruit and an increase of 5.36 per cent of uninjured fruit over the one-spray block (Plat I).

The percentages of sound fruit from Plats I and III show very little difference in favor of a coarse spray over a mist spray; that is, 2.73 per cent in favor of the former.

In Table III are shown the places of entrance into apples of the total larvæ for the season for each tree of each plat and also the percentages, by plats, entering the fruit at the calyx, side, and stem. These data have been given in order to show what effect the methods of spraying might have upon the places of entrance into fruit by larvæ. The unsprayed plat (Plat V) may be taken to indicate the normal behavior of the larvæ and shows that of the first brood 76.84 per cent and of the second brood 80.34 per cent entered the apples at the calyx ends.

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909.*

PLAT I. ONE SPRAY (BORDEAUX NOZZLES).

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	......	......	......	......	......	......	......	1
Side	5	4	1	3	1	2	1	2
Stem	......	......	......	......	......	......	......	......
Total	5	4	1	3	1	2	1	3
Second brood:								
Calyx	91	70	69	20	32	31	54	55
Side	557	400	323	77	137	172	198	235
Stem	53	48	27	18	12	24	34	25
Total	701	518	419	115	181	227	286	315

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT I. ONE SPRAY—Continued.

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	2	1	......	......	......	4	15.38	......
Side	1	1	1	......	......	22	84.62	......
Stem	......	......	......	......	......	......	......	......
Total	3	2	1	......	......	26	......	......
Second brood:								
Calyx	32	24	26	......	......	504	15.97	......
Side	110	80	89	......	......	2,378	75.30	......
Stem	11	9	15	......	......	276	8.73	......
Total	153	113	130	......	......	3,158	......	3,184

PLAT III. ONE SPRAY (VERMOREL NOZZLES).

Total number of larvæ and places of entrance of fruit for each tree, by broods.								
Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	2	......	......	......	......	......	1	......
Side	4	4	2	1	1	1	9	......
Stem	......	......	......	......	......	......	......	......
Total	6	4	2	1	1	1	10	......
Second brood:								
Calyx	141	103	105	158	96	70	64	66
Side	208	163	157	224	198	154	136	121
Stem	49	28	24	50	30	25	21	16
Total	398	294	286	432	324	249	221	203

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	......	......	......	......	......	3	12.00	......
Side	......	......	......	......	......	22	88.00	......
Stem	......	......	......	......	......	......	......	......
Total	......	......	......	......	......	25	......	......
Second brood:								
Calyx	74	......	......	......	......	877	33.20	......
Side	147	......	......	......	......	1,508	57.10	......
Stem	13	......	......	......	......	256	9.70	......
Total	234	......	......	......	......	2,641	......	2,666

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT IV. DEMONSTRATION.

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	....	....	....		....	....	....	2
Side	1	....	4	....	1	....	....	1
Stem	....	....	2	....	....	....	....	1
Total	1	....	6	....	1	....	....	4
Second brood:								
Calyx	14	26	41	6	16	16	32	29
Side	20	14	45	10	5	7	25	21
Stem	1	....	3	....	1	1	1	3
Total	35	40	89	16	22	24	58	53

Total number of larvæ and places of entrance of fruit for each tree, by broods.						Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
Place of entrance.	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	4	1	1	......	......	8	36.40	....
Side	3	....	....	......	......	10	45.40	....
Stem	....	1	....	......	......	4	18.20	....
Total	7	2	1	......	......	22	....	....
Second brood:								
Calyx	79	47	22	......	......	328	55.50	....
Side	65	18	17	......	......	247	41.80	....
Stem	5	....	1	......	......	16	2.70	....
Total	149	65	40	......	......	591	....	613

PLAT V. UNSPRAYED.

Total number of larvæ and places of entrance of fruit for each tree, by broods.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
First brood:								
Calyx	64	102	32	132	52	96	45	25
Side	23	26	4	33	14	15	12	7
Stem	6	5	1	5	10	6	7	4
Total	93	133	37	170	76	117	64	36
Second brood:								
Calyx	579	464	139	463	295	588	513	197
Side	102	67	34	69	58	125	94	49
Stem	28	23	7	26	18	31	32	6
Total	709	554	180	558	371	744	639	252

TABLE III.—*Places of entrance into fruit by total larvæ of the codling moth for each tree of each plat. Siloam Springs, Ark., 1909*—Continued.

PLAT V. UNSPRAYED—Continued.

Brood and place of entrance.	Number of larvæ for each tree.					Total for plat.	Percentage of larvæ by broods entering at calyx, side, and stem.	Total larvæ, first and second broods.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.			
First brood:								
Calyx	31	258	55	63	133	1,088	76.84	
Side	9	36	19	23	33	254	17.94	
Stem	2	12	4	1	11	74	5.27	
Total	42	306	78	87	177	1,416		
Second brood:								
Calyx	489	458	535	398	353	5,471	80.34	
Side	98	89	81	94	96	1,056	15.51	
Stem	28	11	29	29	15	283	4.15	
Total	615	558	645	521	464	6,810		8,226

In the case of the sprayed plats, as would be expected, the proportion entering at the calyx is greatly reduced, and there is a corresponding increase in the proportion entering the fruit at the side, owing to the lesser efficiency of the spray at the latter place. This is shown for each of the plats in Table IV.

TABLE IV.—*Places of entering apples, shown in percentages, of total larvæ of first and second broods of the codling moth combined. Siloam Springs, Ark., 1909.*

Plat No.	Percentage of larvæ entering—				Total larvæ, first brood.	Total larvæ, second brood.	Total larvæ, first and second broods.
	Calyx.	Side.	Stem.	Total			
I. One-spray, Bordeaux nozzles	15.96	75.38	8.66	100.00	26	3,158	3,184
III. One-spray, Vermorel nozzles	33.01	57.39	9.60	100.00	25	2,641	2,666
IV. Demonstration	54.81	41.93	3.26	100.00	22	592	613
V. Unsprayed	79.73	15.93	4.34	100.00	1,416	6,810	8,226

As between the several sprayed plats there is considerable variation in the number of apples wormy at calyx, side, and stem, which is of significance in connection with the character of the treatments given. To compare these points better Table V has been prepared.

TABLE V.—*Efficiency of the one-spray and demonstration treatments as shown by the percentages of wormy apples. Siloam Springs, Ark., 1909.*

Plat No.	Percentage of wormy apples.[a]				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
I. One-spray, Bordeaux nozzles	1.18	5.54	0.64	7.24	3,120	43,152
III. One-spray, Vermorel nozzles	3.32	5.57	.97	9.97	2,654	26,534
IV. Demonstration	1.03	.79	.20	1.88	607	32,451
V. Unsprayed	26.85	5.36	1.46	33.26	8,120	24,428

[a] As some apples were entered at more than one place, the sums of the percentages for calyx, side, and stem slightly exceed the total percentages of wormy apples.

A comparison of the figures for the different plats in Table V shows as to calyx entrance for the two broods about the same degree of protection in the case of Plats I and IV, while as between Plats I and III, both involving the one-spray method, there is a difference in favor of a coarser as against a mist spray of 1.14 per cent of the total crop. The figures on side entrance show that neither of the one-spray treatments afforded any protection to the side of the fruit, while the demonstration treatment saved 4.57 per cent of the crop by preventing side entrance. In comparing the total efficiency of the different treatments, it will be seen that there was a saving of 26.02 per cent of the crop in Plat I, 23.29 per cent in Plat III, and 31.38 per cent in Plat IV. The superiority of the demonstration treatment was mostly due to the prevention of side worminess.

In order to determine what effect the respective treatments might have on the proportion of fruit which dropped and that which remained on the trees until picking time the following table (Table VI) was prepared from the data in the previous tables:

Table VI.—*Comparison of amounts of drop-fruit during season on the several plats. Siloam Springs, Ark., 1909.*

Plat No.	Number of trees.	Fruit from ground.							
		First brood.				Second brood.			
		Wormy.	Sound.	Total.	Per cent sound.	Wormy.	Sound.	Total.	Per cent sound.
I.	11	26	10,202	10,228	99.74	1,449	7,663	9,112	84.09
III.	9	25	5,314	5,339	99.53	1,249	5,997	7,246	82.76
IV.	11	22	8,970	8,992	99.74	240	5,513	5,753	95.82
V.	13	945	8,109	9,054	89.56	5,471	5,742	11,213	51.20

Plat No.	Number of trees.	Fruit from tree.				Total fruit.				Percentage of drop-fruit.
		Wormy.	Sound.	Total.	Per cent sound.	Wormy.	Sound.	Total.	Per cent sound.	
I.	11	1,645	22,167	23,812	93.09	3,120	40,032	43,152	92.76	44.81
III.	9	1,371	12,578	13,949	90.17	2,645	23,889	26,534	90.03	47.42
IV.	11	345	17,361	17,706	98.05	607	31,844	32,451	98.12	45.43
V.	13	1,704	2,457	4,161	59.04	8,120	16,308	24,428	66.76	82.96

As will be noted, the highest percentage of drop-fruit was on the unsprayed plat, namely, 82.96, with 47.42 per cent drop-fruit from Plat III. Plats I and IV (the one-spray and demonstration treatments) show a difference in favor of the demonstration plat of only 0.62 per cent, an amount practically negligible. The percentage of drop-fruit, including fallen fruit from all causes, is shown, but it should be remembered that fruit from all plats, except the check, was largely protected from fungous troubles by applications of Bordeaux mixture.

THE PLUM CURCULIO.

Throughout the season the drop-fruit and the fruit on trees at picking time from four of the plats in the Jones orchard were carefully examined as to injury by the plum curculio. The results of examinations are given in detail in Table VII.

TABLE VII.—*Injury by plum curculio for entire season on Plats I, III, IV, and V, sprayed in the codling-moth experiments. Siloam Springs, Ark., 1909.*

PLAT I. ONE-SPRAY.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of punctures	1,979	1,713	2,613	683	268	1,012	638	1,200
Number of fruit punctured	1,179	915	687	387	208	532	370	706
Number of sound fruit	4,510	3,898	3,109	2,363	3,238	3,236	2,937	4,737
Number of fruit	5,689	4,813	3,796	2,750	3,446	3,768	3,307	5,443
Per cent free from injury	79.27	80.98	81.90	85.92	93.96	85.88	88.81	87.02

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	642	319	642	....	....	11,709	....
Number of fruit punctured	364	216	335	....	....	5,899	....
Number of sound fruit	3,280	2,436	3,560	....	....	37,304	....
Number of fruit	3,644	2,652	3,895	....	....	43,203	....
Per cent free from injury	90.01	91.85	91.39	....	....	....	86.34

PLAT III. ONE-SPRAY.

	Number of punctured and sound fruit etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of punctures	2,321	721	919	788	560	1,790	1,756	732
Number of fruit punctured	1,051	349	533	368	358	795	727	372
Number of fruit free from injury	3,698	2,339	2,211	2,284	1,883	2,775	2,154	1,620
Number of fruit	4,749	2,688	2,744	2,652	2,241	3,570	2,881	1,992
Per cent free from injury	77.86	87.01	80.57	86.12	84.02	77.73	74.76	81.32

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	1,629	....	....	....	....	11,216	....
Number of fruit punctured	727	....	....	....	....	5,280	....
Number of fruit free from injury	1,493	....	....	....	....	20,457	....
Number of fruit	2,220	....	....	....	....	25,737	....
Per cent free from injury	67.25	....	....	....	....	....	79.48

TABLE VII.—*Injury by plum curculio for entire season on Plats I, III, IV, and V, sprayed in the codling-moth experiments. Siloam Springs, Ark., 1909*—Continued.

PLAT IV. DEMONSTRATION.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of punctures	1,293	562	773	98	430	432	1,025	877
Number of fruit punctured	746	301	437	74	266	200	498	467
Number of fruit free from injury	2,790	1,589	4,639	1,591	2,879	1,465	1,998	2,705
Number of fruit	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172
Per cent free from injury	78.90	84.07	91.39	95.55	91.54	87.98	80.04	85.27

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	13,129	254	1,429			10,302	
Number of fruit punctured	3,656	140	769			5,554	
Number of fruit free from injury	,135	1,817	2,289			26,897	
Number of fruit	4,791	1,957	3,058			32,451	
Per cent free from injury	65.43	92.84	74.85				82.88

PLAT V. UNSPRAYED.

	Number of punctured and sound fruit, etc., per tree in each plat.							
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Number of puncture	6,623	6,230	4,331	10,068	3,372	9,527	14,727	4,714
Number of fruit punctured	2,130	1,595	948	1,522	999	2,299	2,724	1,070
Number of fruit free from injury	430	106	47	16	207	202	97	86
Number of fruit	2,560	1,701	995	1,538	1,206	2,501	2,821	1,156
Per cent free from injury	16.79	6.23	4.72	1.04	17.16	8.07	3.43	7.43

	Number of punctured and sound fruit, etc., per tree in each plat.					Total for plat.	Total per cent fruit free from injury.
	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.		
Number of punctures	6,143	8,707	6,921	5,984	6,739	94,086	
Number of fruit punctured	1,936	2,117	1,605	1,517	1,750	22,212	
Number of fruit free from injury	387	141	114	91	310	2,234	
Number of fruit	2,323	2,258	1,719	1,608	2,060	24,446	
Per cent free from injury	16.65	6.24	6.63	5.65	15.04		8.85

All punctures, whether egg or feeding, are classed together under "Number of punctures." The total percentage of fruit free from curculio injury includes fruit entirely free from feeding and egg punctures, and has no reference to injury from other insects, as the codling moth or lesser apple worm. Curiously, in the Siloam Springs work the one-spray block (Plat I) shows the maximum percentage of fruit free from curculio attack, injury on the demonstration plat exceeding in this regard that on the one-spray plat by 3.46 per cent. It should be noted, however, that Plat IV was adjacent to the unsprayed block (see fig. 2) and there was unquestionably considerable overflow of curculio, as on this latter the beetles were quite abundant, as shown by the low total percentage of uninjured fruit, namely, 8.85 per cent. In view of the habits of the curculio in ovipositing and feeding over a considerable period (six to eight weeks or more), the results from the one-spray method are the more surprising, and it would appear that the single treatment resulted in their almost complete destruction.

In Table VIII are brought together data showing the effects of the treatments in the control of the three principal insect enemies of the fruit, namely, the codling moth, the plum curculio, and the lesser apple worm (*Enarmonia prunivora* Walsh). The value of the one-spray method is here put to the severest possible test so far as controlling insect enemies of the fruit is concerned. It will be noted that when these three insects are taken into account somewhat better results were secured from Plat IV, which received the demonstration treatment, namely, 81.19 per cent sound fruit, as against 79.60 per cent sound fruit from the one-spray plat. The unsprayed plat (V) shows a very low percentage of fruit free from injury by these three insects, namely 6.94 per cent.

TABLE VIII.—*Effect of treatments on the three principal fruit insects and total percentage of sound fruit. Siloam Springs, Ark., 1909.*

PLAT I. ONE-SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	1,179	915	687	387	208	532	370	706
Injured by codling moth	703	522	419	118	181	222	286	315
Injured by lesser apple worm	71	74	41	6	31	17	19	30
Number injured apples	1,778	1,403	1,062	486	409	739	652	991
Number uninjured apples	3,911	3,410	2,734	2,264	3,037	3,023	2,655	4,452
Total number apples	5,689	4,813	3,796	2,750	3,446	3,762	3,307	5,443

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	364	216	335	......	......	5,899	86.34	......
Injured by codling moth	110	113	131	......	......	3,120	92.74	......
Injured by lesser apple worm	10	5	5	......	......	309	99.29	......
Number injured apples	473	349	460	......	......	8,802	......	......
Number uninjured apples	3,126	2,303	3,433	......	......	34,348	......	79.60
Total number apples	3,599	2,652	3,895	......	......	43,152	......	......

PLAT III. ONE-SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	1,051	349	533	368	358	795	727	372
Injured by codling moth	397	298	286	431	321	247	231	200
Injured by lesser apple worm	29	19	14	32	40	22	26	12
Number injured apples	1,363	525	772	806	684	1,010	919	551
Number uninjured apples	3,386	2,960	1,972	1,846	1,557	2,560	1,962	1,441
Total number apples	4,749	3,485	2,744	2,652	2,241	3,570	2,881	1,992

TABLE VIII.—*Effect of treatments on the three principal fruit insects and total percentage of sound fruit. Siloam Springs, Ark., 1909*—Continued.

PLAT III. ONE-SPRAY—Continued.

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	727	....	....	....	....	5,280	79.48	....
Injured by codling moth	234	....	....	....	....	2,645	90.03	....
Injured by lesser apple worm	9	....	....	....	....	203	99.24	....
Number injured apples	786	....	....	....	....	7,416	....	....
Number uninjured apples	1,434	....	....	....	....	19,118	....	72.05
Total number apples	2,220	....	....	....	....	26,534	....	....

PLAT IV. DEMONSTRATION.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	746	301	437	74	266	200	498	467
Injured by codling moth	36	41	93	16	22	23	57	57
Injured by lesser apple worm	6	1	6	1	0	2	3	0
Number injured apples	826	332	509	90	287	222	545	518
Number uninjured apples	2,710	1,558	4,567	1,575	2,858	1,443	1,951	2,654
Total number apples	3,536	1,890	5,076	1,665	3,145	1,665	2,496	3,172

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	1,656	140	769	....	....	5,554	82.88	....
Injured by codling moth	154	67	41	....	....	607	98.12	....
Injured by lesser apple worm	14	6	3	....	....	42	99.87	....
Number injured apples	1,761	207	806	....	....	6,103	....	....
Number uninjured apples	3,030	1,750	2,252	....	....	26,348	....	81.19
Total number apples	4,791	1,957	3,058	....	....	32,451	....	....

PLAT V. UNSPRAYED.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.
Injured by plum curculio	2,130	1,595	948	1,522	999	2,299	2,724	1,070
Injured by codling moth	795	679	217	716	450	823	697	287
Injured by lesser apple worm	213	140	52	222	89	224	309	91
Number injured apples	2,250	1,605	959	1,528	1,072	2,355	2,740	1,076
Number uninjured apples	310	78	36	10	134	146	81	80
Total number apples	2,560	1,683	995	1,538	1,206	2,501	2,821	1,156

	Tree 9.	Tree 10.	Tree 11.	Tree 12.	Tree 13.	Total for plat.	Per cent free from injury.	Total per cent free from injury.
Injured by plum curculio	1,936	2,117	1,605	1,517	1,750	22,212	8.85	....
Injured by codling moth	652	859	709	592	614	8,120	66.75	....
Injured by lesser apple worm	120	218	139	174	77	2,068	91.50	....
Number injured apples	1,987	2,148	1,631	1,556	1,824	22,731	....	....
Number uninjured apples	336	110	88	52	236	1,697	....	6.94
Total number apples	2,323	2,258	1,719	1,608	2,060	24,428	....	....

EXPERIMENTS IN VIRGINIA.

The experiments in Virginia were carried out in two localities, namely, at Crozet, in the orchard of W. S. Ballard, and at Mount Jackson, in the orchard of the Strathmore Orchard Company.

W. S. Ballard's Orchard.

W. S. Ballard's orchard is located in the eastern foothills of the Blue Ridge Mountains and is composed mostly of the Yellow Newtown (Albemarle Pippin) variety, which sort was used exclusively

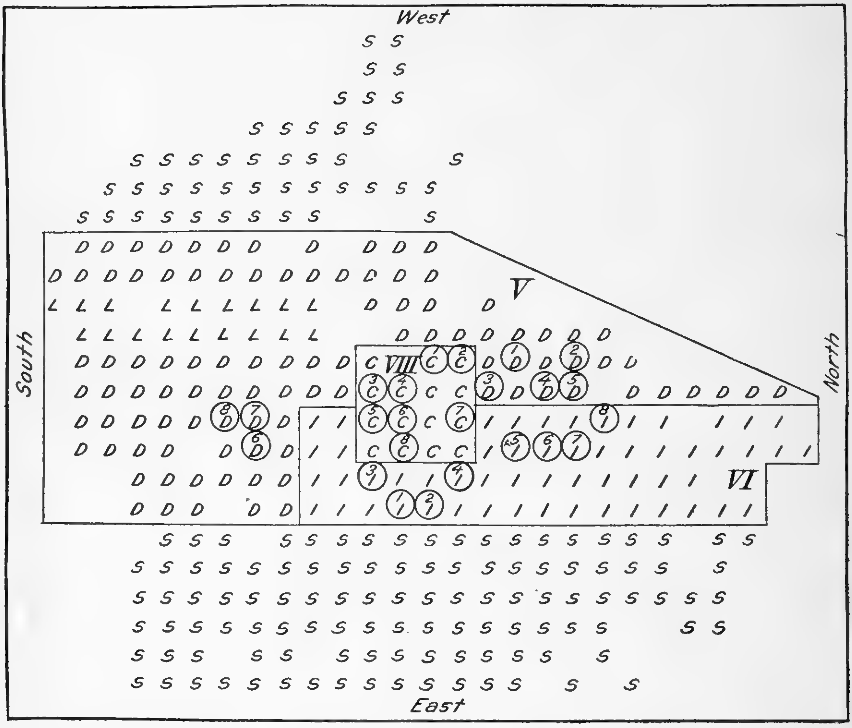

Fig. 35.—Diagram showing arrangement of plats and trees in the W. S. Ballard orchard near Crozet, Va. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Variety, Yellow Newtown (Albemarle Pippin). Trees marked *S* sprayed by owner.

in the experiments. The location of the trees sprayed, with reference to adjacent trees in the orchard, is shown in figure 35. The surrounding trees not included in the experiment were sprayed by the owner. The size of the trees and general character of the location are shown in Plate X, figure 2.

THE CODLING MOTH.

The treatments given and dates of applications are shown in Table IX.

TABLE IX.—*Dates of applications for codling moth and plum curculio, one-spray method. Crozet, Va., 1909.*

Date of application.	Plat V. (Demonstration.)	Plat VI. (One-spray method.)	Plat VIII. (Unsprayed.)
First application, April 27 (after falling of petals).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead 2 pounds to 50 gallons Bordeaux mixture (2-2-50). Pressure 120 to 140 pounds.	Drenched with arsenate of lead 2 pounds to 50 gallons Bordeaux mixture (2-2-50). Pressure 125-160 pounds. Seneca nozzles. 11 gallons per tree.	Unsprayed.
Second application, May 24.	do	Bordeaux mixture only (2-2-50). Not drenched.	Do.
Third application, June 26.	do	do	Do.
Fourth application, July 26-27.	do	do	Do.

Plat V (demonstration) received four applications in all, the Vermorel nozzle being used. The effort was made to spray thoroughly, but none of the trees was drenched. Plat VI (one-spray method) was thoroughly drenched, using Seneca nozzles, applying an average of 11 gallons per tree. This plat received three subsequent applications of Bordeaux mixture only, as shown in the schedule, to protect the fruit from possible infection by bitter rot. Plat VIII was left unsprayed throughout the season for purposes of comparison.

The first application, on April 27, was given just after most of the petals had fallen, and conditions were favorable for the work except that showers interrupted the spraying for about one hour. At the time of the second application, May 24, the weather was showery, but spraying was finished without serious interruption. The third application, on June 26, was interrupted near the close of the work by rain, while the fourth application, on July 26, was made under very favorable conditions, the weather being clear and dry. Comparatively little bitter rot developed during the season, even on the unsprayed plat. A heavy hail, however, which occurred during late June, badly injured the fruit and foliage. It was noticed that the hail injury to the fruit resulted in a much greater proportion of codling-moth larvæ entering on the side, and this fact must be taken into account in the consideration of the results.

Table X gives the total wormy fruit and fruit free from codling-moth injury for the entire season for the eight count trees of each plat, the numbers of the trees in the figure agreeing with those in the table.

TABLE X.—*Number of sound and wormy apples for each tree from one-spray, demonstration, and unsprayed plats. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	90	115	68	191	173	49	54	87	827	....
Sound	712	1,344	651	2,224	1,859	1,259	2,958	2,243	13,250	....
Total	802	1,459	719	2,415	2,032	1,308	3,012	2,330	14,077	....
Per cent sound	88.78	92.12	90.55	92.10	91.49	96.26	98.21	96.27	....	94.13

PLAT VI. ONE SPRAY.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	498	367	627	1,681	445	362	391	462	3,320	....
Sound	2,080	2,166	4,478	1,150	2,800	1,617	1,650	1,577	17,518	....
Total	2,578	2,533	5,105	1,318	3,245	1,979	2,041	2,039	20,838	....
Per cent sound	80.30	85.52	87.72	87.26	86.29	81.71	80.90	77.35	....	84.07

PLAT VIII. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of sound fruit.
Wormy	1,165	1,593	545	560	1,641	1,444	1,089	1,001	9,038	....
Sound	2,258	2,089	271	456	1,470	1,544	904	1,206	10,198	....
Total	3,423	3,682	816	1,016	3,111	2,988	1,993	2,207	19,236	....
Per cent sound	65.97	56.79	33.22	44.89	47.90	51.68	45.31	54.65	....	53.02

Plat V, which received the demonstration treatment, gave 94.13 per cent fruit free from codling-moth injury, as against 84.07 per cent fruit free from this insect on the one-spray plat, a difference in favor of the demonstration treatment of 10.06 per cent. The check or unsprayed plat (VIII) shows 53.02 per cent fruit free from codling-moth injury, and there is thus a gain in sound fruit by the demonstration treatment of 41.11 per cent and by the one-spray method a gain of 31.05 per cent of sound fruit. As will be seen from the foregoing table, there were counted in Plats V, VI, and VIII, respectively, 14,077, 20,838, and 19,236 apples, a total for all plats of 54,151. Undoubtedly the results from the one-spray plat are less favorable than would have been the case had there been no hail. The injured places on the sides of the fruit permitted ready entrance of the larvæ, as indicated on all plats by the relatively high percentage of larvæ which entered the fruit on the side. This condition is shown in Table XI, which gives the places of entrance of the fruit for each tree of each plat for the total larvæ of the two broods throughout the season.

TABLE XI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

Place of entrance.	Total number of larvæ of fruit for each tree, first and second broods combined.								Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.			
First and second broods:											
Calyx	8	6	5	13	15	2	4	11	64	7.73	....
Side	76	105	59	159	148	46	46	68	707	85.49	....
Stem	6	4	4	19	10	1	4	8	56	6.78	....
Total	90	115	68	191	173	49	54	87	827	100.00	827

PLAT VI. ONE SPRAY.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	35	12	26	7	12	23	17	19	151	4.55	....
Side	443	331	567	150	407	319	344	415	2,976	89.64	....
Stem	20	24	34	11	26	20	30	28	193	5.81	....
Total	498	367	627	168	445	362	391	462	3,220	100.00	3,220

PLAT VIII. UNSPRAYED.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	527	888	320	258	878	677	512	493	4,553	50.38	....
Side	483	508	158	231	561	620	439	429	3,429	37.94	....
Stem	155	197	67	71	202	147	138	79	1,056	11.68	....
Total	1,165	1,593	545	560	1,641	1,444	1,089	1,001	9,038	100.00	9,038

The efficiency of the one-spray and demonstration treatments in preventing worminess is shown in condensed form in Table XII. Here it will be seen that the one-spray method was nearly as effective as the demonstration in preventing calyx entrance, but gave little benefit in regard to side infestation.

TABLE XII.—*Efficiency of the different treatments as shown by the percentages of wormy apples. Crozet, Va., 1909.*

Plat No.	Percentage of wormy apples.				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		
V. Demonstration	0.45	5.02	0.40	5.87	827	14,077
VI. One-spray	0.73	14.28	0.92	15.93	3,320	20,838
VIII. Unsprayed	23.67	17.82	5.49	46.98	9,038	19,236

THE PLUM CURCULIO.

The effect of the treatments in the W. S. Ballard orchard in controlling the plum curculio on Plats V, VI, and VIII is shown in Table XIII. Egg and feeding punctures are combined in the table under "No. punctures."

TABLE XIII.—*Injury by plum curculio for entire season, Plats V, VI, and VIII. Crozet, Va., 1909.*

PLAT V. DEMONSTRATION.

	Number of punctured and sound apples, etc., per tree in each plat.								Total for plats.	Total per cent of fruit free from injury.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.		
No. punctures	157	275	163	524	668	162	395	328	2,672	....
No. fruit punctured	115	187	103	345	463	114	267	252	1,846	....
No. sound fruit	687	1,272	616	2,070	1,569	1,194	2,747	2,076	12,231	....
No. fruit	802	1,459	719	2,415	2,032	1,308	3,014	2,328	14,077	....
Per cent free from injury	85.66	87.18	85.67	85.71	77.21	91.28	91.14	89.17	....	86.89

PLAT VI. ONE SPRAY.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of fruit free from injury.
No. punctures	1,510	1,290	2,143	360	1,095	647	775	823	8,644	....
No. fruit punctured	961	730	1,347	238	719	405	521	511	5,432	....
No. sound fruit	1,617	1,803	3,758	1,080	2,526	1,574	1,520	1,528	15,406	....
No. fruit	2,578	2,533	5,105	1,318	3,245	1,979	2,041	2,039	20,838	....
Per cent free from injury	62.72	71.17	73.61	81.94	77.84	79.53	74.96	74.93	....	73.93

PLAT VIII. UNSPRAYED.

	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent of fruit free from injury.
No. punctures	2,746	2,571	705	962	2,490	1,939	1,865	2,300	15,578	....
No. fruit punctured	1,255	1,571	437	531	1,415	1,193	1,098	1,285	8,785	....
No. sound fruit	2,168	2,111	379	485	1,696	1,795	882	806	10,322	....
No. fruit	3,423	3,682	816	1,016	3,111	2,988	1,980	2,091	19,107	....
Per cent free from injury	63.30	57.33	57.33	46.44	47.73	60.00	44.54	38.54	....	54.02

The percentage of fruit uninjured by the curculio in the demonstration block, 86.89 per cent, shows a gain over that of the one-spray plat, 73.93 per cent, of 12.96 per cent, and the gain in percentage of uninjured fruit on the demonstration over the unsprayed plat is 32.87.

ORCHARD OF STRATHMORE ORCHARD COMPANY.

The orchard of the Strathmore Orchard Company is located near Mount Jackson, in the Shenandoah Valley of Virginia. The size of the trees and general appearance of the orchard are indicated in Plate XI, figure 1. The location of the trees under experiment with respect to the rest of the orchard is shown in figure 36. All trees not in the experiment were sprayed by the owners. The treatments given and dates of application are stated in Table XIV.

TABLE XIV.—*Dates of applications for codling moth and plum curculio, one-spray method. Mount Jackson, Va., 1909.*

Date of application.	Plat XIII. (Demonstration.)	Plat XV. (One-spray method.)	Plat XVII. (Unsprayed.)
First application, May 6-7 (after falling of petals).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (1-1-50). Pressure 120 to 140 pounds. 4.7 gallons per tree.	Drenched with arsenate of lead, 2 pounds to 50 gallons water. Pressure 175 pounds. Seneca nozzles. 8.1 gallons per tree.	Unsprayed.
Second application, May 28-29.	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (2-2-50).	Bordeaux mixture only (2-2-50). Not drenched.	Do.
Third application, July 8-9.	.....do........................	.....do........................	Do.

FIG. 1.—VIEW IN ORCHARD OF THE STRATHMORE ORCHARD COMPANY, NEAR MOUNT JACKSON, VA. (ORIGINAL.)

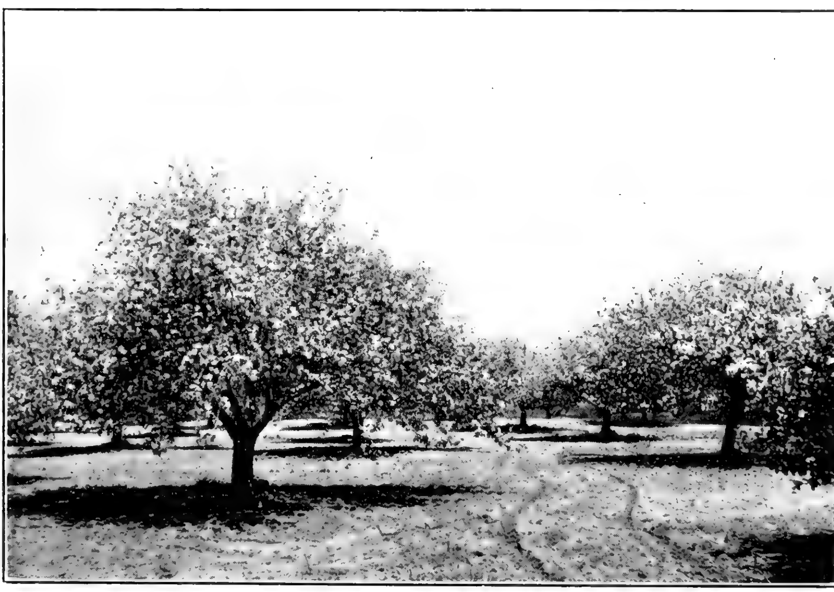

FIG. 2.—VIEW IN THE E. H. HOUSE ORCHARD, NEAR SAUGATUCK, MICH. (ORIGINAL.)

The demonstration plat (XIII) received in all three treatments of a combined Bordeaux mixture and arsenate of lead spray. Plat XV (one-spray method) received only one arsenate of lead treatment just after the falling of the petals, but two additional applications of Bordeaux mixture were given to protect the fruit and foliage from fungous diseases. Plat XVII was left unsprayed throughout. The Ben Davis variety of apple was used entirely in the experiments.

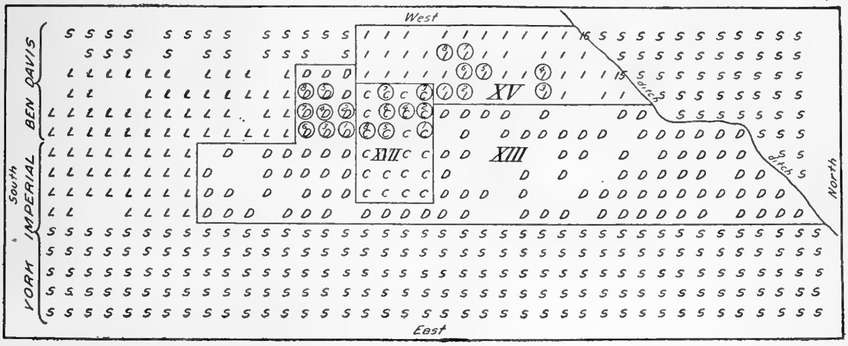

FIG. 36.—Diagram showing arrangement of plats and trees in the orchard of the Strathmore Orchard Co., near Mount Jackson, Va. Trees marked *S* sprayed by the owner; trees marked *L* used for experiments with lime-sulphur wash. Circles indicate count trees, the numbers agreeing with those in the tables.

THE CODLING MOTH.

The results of the respective treatments in the control of the codling moth are shown in Table XV.

TABLE XV.—*Number of sound and wormy apples for each tree from one-spray, demonstration, and unsprayed plats. Mount Jackson, Va., 1909.*

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Total per cent sound.
PLAT XIII. DEMONSTRATION.										
Wormy	200	136	155	83	173	168	119	150	1,184	....
Sound	1,666	1,172	3,311	625	1,494	3,618	944	2,278	15,108	....
Total	1,866	1,308	3,466	708	1,667	3,786	1,063	2,428	16,292	....
Per cent sound	89.29	89.61	95.53	88.28	89.69	95.57	88.81	93.83	....	92.74
PLAT XV. ONE SPRAY.										
Wormy	250	253	86	186	250	219	122	257	1,623	....
Sound	3,577	3,404	589	730	1,429	3,261	847	4,042	17,879	....
Total	3,827	3,657	675	916	1,679	3,480	969	4,299	19,502	....
Per cent sound	93.49	93.09	87.26	79.70	85.12	93.71	87.41	94.03	....	91.68
PLAT XVII. UNSPRAYED.										
Wormy	1,913	1,425	865	983	1,538	1,792	2,027	1,247	11,790	....
Sound	2,013	1,684	965	524	1,651	2,361	3,094	1,548	13,840	....
Total	3,926	3,109	1,830	1,507	3,189	4,153	5,121	2,795	25,630	....
Per cent sound	51.23	54.17	52.19	34.78	51.78	56.86	60.42	55.42	....	54.00

The influence of the treatments on the places of entrance of fruit by the larvæ of the first and second broods combined for the respective plats is shown in Table XVI.

TABLE XVI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Mount Jackson, Va., 1909.*

PLAT XIII. DEMONSTRATION.

Place of entrance.	Total number of larvæ of fruit for each tree, first and second broods combined.								Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.			
First and second broods:											
Calyx	32	14	15	16	20	26	15	24	162	13.68	....
Side	154	111	122	58	136	125	92	116	914	77.20	....
Stem	14	11	18	9	17	17	12	10	108	9.12	....
Total	200	136	155	83	173	168	119	150	1,184	100.00	1,184

PLAT XV. ONE SPRAY.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	13	32	6	16	25	19	18	17	146	8.99	....
Side	190	193	74	143	173	183	91	214	1,261	77.70	....
Stem	47	28	6	27	52	17	13	26	216	13.31	....
Total	250	253	86	186	250	219	122	257	1,623	100.00	1,623

PLAT XVII. UNSPRAYED.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Total for plats.	Percentages of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:											
Calyx	1,466	1,063	699	762	1,232	1,377	1,584	969	9,152	77.62	....
Side	332	265	119	141	203	295	353	209	1,917	16.26	....
Stem	115	97	47	80	103	120	90	69	721	6.12	....
Total	1,913	1,425	865	983	1,538	1,792	2,027	1,247	11,790	100.00	11,790

For more ready comparison of the efficiency of the treatments, Table XVII is given, from which it will be seen that the demonstration and the one-spray treatments were about equally effective in protecting the calyx and that neither was satisfactory in controlling worms entering the side. The difference in total efficiency between the demonstration and the one-spray plats is quite small, namely, 1.06 per cent in favor of the former. The unsprayed trees show 46 per cent of wormy fruit, so there is a total saving of 38.44 per cent of the crop by the demonstration treatment and 37.68 per cent by the one-spray.

TABLE XVII.—*Efficiency of the one-spray and demonstration treatments as shown by the percentages of wormy apples. Mount Jackson, Va., 1909.*

Plat No.	Percentage of wormy apples.				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*		
XIII (demonstration)	0.99	5.61	0.66	7.26	1,184	16,292
XV (one-spray)	.75	6.46	1.11	8.32	1,623	19,502
XVII (unsprayed)	35.71	7.48	2.81	46.00	11,790	25,630

THE PLUM CURCULIO.

The plum curculio proved to be unusually destructive in the Strathmore orchard, which had not been plowed for at least two years and had grown up in grass and sod. The results of the respective treatments in the control of this insect are shown in Table XVIII, and as will be noted the percentage of fruit free from curculio injury is in all cases comparatively low. Nevertheless the one-spray treatment shows a gain of 17.08 per cent of fruit free from injury over the demonstration treatment, and a gain of 30.67 per cent of fruit free from injury over the unsprayed trees. The location of the trees in the respective plats does not indicate a more favorable place as regards liability to curculio injury for the one-spray block and the notably higher benefit of the single treatment in the control of the curculio on this plat is not understood.

TABLE XVIII.—*Injury by the plum curculio for entire season, Plats XIII, XV, and XVII. Mount Jackson, Va., 1909.*

	Number of punctured and sound apples, etc., per tree in each plat.								Total for plat.	Total per cent fruit free from injury.
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.		
PLAT XIII. DEMONSTRATION.										
No. punctures	2,961	2,391	3,067	932	3,013	4,040	1,486	2,869	20,759	....
No. fruit punctured	1,367	755	1,631	441	1,257	2,197	612	1,382	9,642	....
No. sound fruit	499	553	1,835	267	410	1,589	451	1,047	6,651	....
No. fruit	1,866	1,308	3,466	708	1,667	3,786	1,063	2,429	16,293	....
Per cent free from injury	26.79	42.27	52.94	33.71	24.58	41.97	42.42	43.10	....	40.82
PLAT XV. ONE SPRAY.										
No. punctures	2,782	1,800	633	1,032	1,449	2,159	987	3,153	13,995	....
No. fruit punctured	1,507	1,788	303	494	754	1,212	447	1,735	8,240	....
No. sound fruit	2,320	1,869	372	495	925	2,268	522	2,564	11,335	....
No. fruit	3,827	3,657	675	989	1,679	3,480	969	4,299	19,575	....
Per cent free from injury	60.62	51.10	55.11	50.15	55.09	65.17	53.86	59.64	....	57.90
PLAT XVII. UNSPRAYED.										
No. punctures	7,336	4,497	2,212	2,888	5,030	6,122	8,779	4,904	41,768	....
No. fruit punctured	3,186	2,226	1,079	1,226	2,399	2,823	3,611	2,107	18,657	....
No. sound fruit	740	883	761	282	790	1,330	1,510	688	6,984	....
No. fruit	3,926	3,109	1,840	1,508	3,189	4,153	5,121	2,795	25,641	....
Per cent free from injury	18.84	28.40	41.35	18.61	24.77	32.04	29.46	24.61	....	27.23

EXPERIMENTS IN MICHIGAN.

The experiments in Michigan were carried out in the vicinity of Saugatuck, in the orchard of Mr. E. H. House. The location of the plats in the orchard and of the count trees in the respective plats is shown in figure 37. The size of the trees is illustrated in Plate XI, figure 2. This orchard included trees of the Wagener, Ben Davis, and Baldwin varieties, and an equal number of trees of each variety was used for counts in the respective plats. As in the work elsewhere, all drop-fruit during the season, as well as that from the trees at picking time, was taken into account and classified as to injury or otherwise. Also the work of the two broods of the codling moth was carefully separated by removing from the trees at the period of maximum maturation of the first-brood larvæ all fruit injured by the first brood, thus eliminating entirely from later counts first-brood work. The infested apples, however, were placed on the ground under the respective trees, so that development of second-brood larvæ would be in no wise interfered with.

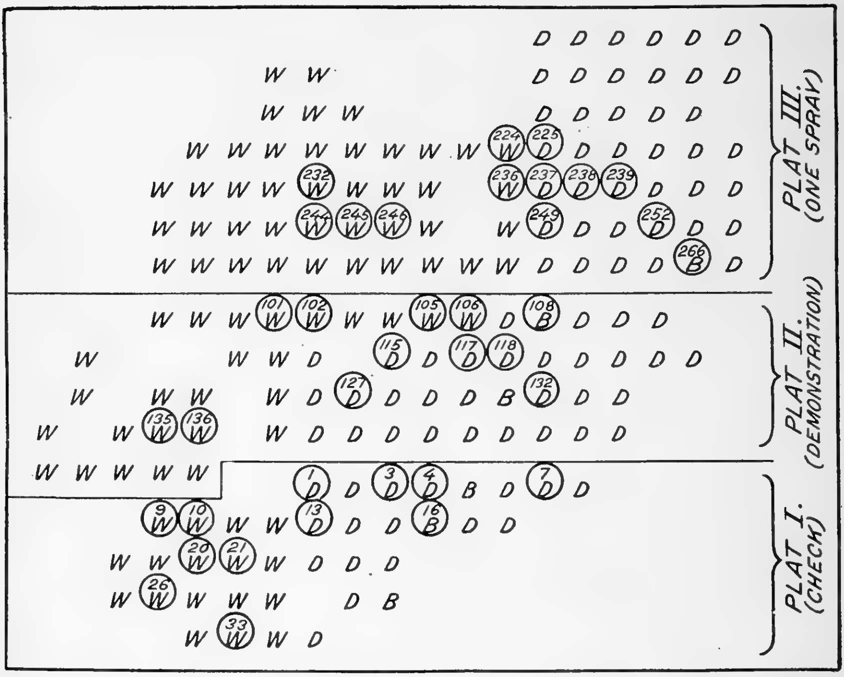

FIG. 37.—Diagram illustrating arrangement of plats and position of trees in the E. H. House orchard, near Saugatuck, Mich.: *D*, Ben Davis; *B*, Baldwin; *W*, Wagener. Count trees are indicated by circles, the numbers agreeing with those in the tables.

The treatments given and dates of application are indicated in Table XIX.

TABLE XIX.—*Dates of applications for the codling moth and plum curculio, one-spray method. Saugatuck, Mich., 1909.*

Date of application.	Plat I. (Unsprayed.)	Plat II. (Demonstration.)	Plat III. (One-spray method.)
First application (before blossoms opened), May 20–21.	Unsprayed....	Not drenched. Vermorel nozzles. Mist spray. Bordeaux mixture (4-4-50).	Drenched. Bordeaux nozzles. Coarse spray. Bordeaux mixture (4-4-50).
Second application, June 3–9, after falling of petals.	.....do........	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons Bordeaux mixture (4-4-50). Pressure, 125 pounds.	Drenched. Bordeaux nozzles. Coarse spray. Arsenate of lead, 1 pound to 50 gallons water. Pressure, 175 to 200 pounds.
Third application, June 21–22.	.....do........	.....do........	Bordeaux mixture only (4-4-50). June 10–11 and again June 21–22.
Fourth application, August 7–9.	.....do........	.....do........	Bordeaux mixture only (4-4-50).

Plat I was left unsprayed for purposes of comparison. Plat II (demonstration block) received four applications in all, the first before blooming but after cluster buds had opened, to protect the fruit from apple scab, which during some seasons in the lake region is very troublesome. Plat III (one-spray block) received the first scab treatment of Bordeaux mixture only and an additional treatment with arsenate of lead only at the rate of 1 pound to 50 gallons water immediately after the falling of the petals. This treatment was immediately followed by an application of Bordeaux mixture to prevent scab infection, as it was considered unsafe to apply the fungicide so excessively as the one-spray method required in the use of the arsenical. Plat III received two subsequent applications of Bordeaux mixture only, as shown in the schedule of applications, to further insure freedom from apple scab.

THE CODLING MOTH.

The percentages of wormy and sound fruit for the respective plats for the season are shown in Table XX, and the numbers of trees in the table agree with those in the diagram of the orchard (fig. 37).

TABLE XX.—*Sound and wormy fruit from unsprayed, demonstration, and one-spray plats. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Condition of fruit.	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.
Wormy	663	752	605	166	946	1,207	416
Sound	3,996	5,033	2,947	1,340	1,805	2,676	2,213
Total	4,659	5,785	3,552	1,506	2,751	3,883	2,629
Per cent sound	85.76	87.00	82.96	88.97	65.61	68.91	84.17

Condition of fruit.	Tree 16.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	Total per cent sound.
Wormy	889	651	404	1,041	669	8,409	....
Sound	1,926	2,632	1,276	2,321	1,301	29,466	....
Total	2,815	3,283	1,680	3,362	1,970	37,875	....
Per cent sound	68.14	80.17	75.95	69.03	66.03	....	77.79

PLAT II. DEMONSTRATION.

Condition of fruit.	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.
Wormy	120	122	48	75	96	72	15
Sound	1,505	1,643	2,112	1,775	5,623	3,950	5,781
Total	1,625	1,765	2,160	1,850	5,719	4,022	5,796
Per cent sound	92.61	93.08	97.77	95.94	98.32	98.20	99.74

TABLE XX.—*Sound and wormy fruit from unsprayed, demonstration, and one-spray plats. Saugatuck, Mich., 1909*—Continued.

PLATE II. DEMONSTRATION—Continued.

Condition of fruit.	Tree 118.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	Total per cent sound.
Wormy	25	91	13	245	76	998	....
Sound	5,188	4,336	4,285	3,978	1,644	41,820	....
Total	5,213	4,427	4,298	4,223	1,720	42,818	....
Per cent sound	99.52	97.94	99.69	94.19	95.58	....	97.66

PLAT III. ONE SPRAY.

Condition of fruit.	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.
Wormy	500	103	396	343	118	41	62
Sound	3,113	4,602	3,061	2,753	2,779	3,510	3,062
Total	3,613	4,705	3,457	3,096	2,897	3,551	3,124
Per cent sound	86.16	97.95	88.54	88.92	95.92	98.84	98.01

Condition of fruit.	Tree 244.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	Total per cent sound.
Wormy	452	340	165	62	46	110	2,738	....
Sound	4,107	4,001	2,743	3,381	1,092	1,925	40,129	....
Total	4,559	4,341	2,908	3,443	1,138	2,035	42,867	....
Per cent sound	90.08	92.16	94.32	98.19	95.95	94.59	....	93.61

In the foregoing table the demonstration plat shows an increase of sound fruit over the one-spray method of 4.05 per cent and over the unsprayed plat of 19.87 per cent. There was less injury on the unsprayed trees than usual for that section, due to the small size of the second brood. Only 13 per cent of the first-brood larvæ from bands transformed to moths.

The effect of the treatments on the places of entrance of fruit by larvæ of the first and second broods is shown in Table XXI.

TABLE XXI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

Brood and place of entrance.	Number of larvæ for each tree.							
	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.	Tree 16.
First brood:								
Calyx	133	206	172	65	316	257	168	214
Side	39	24	25	10	28	28	17	40
Stem	5	8	0	0	7	6	4	5
Total	177	238	197	75	351	291	189	259
Second brood:								
Calyx	277	272	274	51	279	316	140	357
Side	213	249	155	39	319	360	87	306
Stem	16	9	15	2	19	30	7	11
Total	506	530	444	92	617	706	234	674

TABLE XXI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909*—Continued.

PLATE I. UNSPRAYED—Continued.

Brood and place of entrance.	Number of larvæ for each tree.					Percentage of larvæ entering.	Total larvæ of first and second broods.
	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.		
First brood:							
Calyx	176	129	442	266	2,544	85.20	....
Side	17	21	68	59	376	12.59	....
Stem	4	5	13	9	66	2.21	....
Total	197	155	523	334	2,986	....	....
econd brood:							
Calyx	208	105	290	183	2,752	50.45	....
Side	240	151	231	181	2,531	46.40	....
Stem	18	6	21	18	172	3.15	....
Total	466	262	542	382	5,455	....	8,441

PLAT II. DEMONSTRATION.

Brood and place of entrance.	Number of larvæ for each tree.							
	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.	Tree 118.
First brood:								
Calyx	....	....	1	....	5	10	2	2
Side	9	12	14	12	8	5	5	4
Stem	....	1	....	....	1	....	....	....
Total	9	13	15	12	14	15	7	6
Second brood:								
Calyx	....	....	....	....	2	....	....	1
Side	146	155	41	81	95	73	8	19
Stem	....	....	....	....	....	....	....	....
Total	146	155	41	81	97	73	8	20

Brood and place of entrance.	Number of larvæ for each tree.					Percentage of larvæ entering.	Total larvæ of first and second broods.
	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.		
First brood:							
Calyx'	8	1	....	2	31	20.95	....
Side	7	1	27	11	115	77.70	....
Stem	....	....	....	....	2	1.35	....
Total	15	2	27	13	148	....	....
Second brood:							
Calyx	1	....	1	1	6	.52	....
Side	95	11	320	93	1,137	99.30	....
Stem	1	....	1	....	2	.18	....
Total	97	11	322	94	1,145	....	1,293

TABLE XXI.—*Places of entrance of fruit by total larvæ for each tree of each plat. Saugatuck, Mich., 1909*—Continued.

PLAT III. ONE SPRAY.

Brood and place of entrance.	Number of larvæ for each tree.							
	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.	Tree 244.
First brood:								
Calyx	5	3	......	2	......	2	1	3
Side	86	6	15	24	7	5	2	31
Stem	2	1	......	1	......	......	......	......
Total	93	10	15	27	7	7	3	34
Second brood:								
Calyx	4	1	6	4	1	1	1	4
Side	356	141	416	370	161	43	75	492
Stem	9	......	......	4	......	......	......	2
Total	369	142	422	378	162	44	76	498

Brood and place of entrance.	Number of larvæ for each tree.						Percentage of larvæ entering.	Total larvæ of first and second broods.
	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.		
First brood:								
Calyx	2	1	1	......	......	20	7.38	......
Side	40	13	6	1	9	245	90.41	......
Stem	......	2	......	......	......	6	2.21	......
Total	42	16	7	1	9	271	......	......
Second brood:								
Calyx	9	......	4	......	2	37	1.30	......
Side	297	176	67	52	131	2,777	97.54	......
Stem	13	4	......	......	1	33	1.16	......
Total	319	180	71	52	134	2,847	......	3,118

A study of the percentages of larvæ of the respective broods entering the calyx, side, and stem ends of the fruit for each plat, as shown in Table XXI, presents some points of interest. On all plats a greater percentage of larvæ of the first brood entered at the calyx than was true of larvæ of the second brood. Thus, on the unsprayed plat (I), 85.20 per cent of the first-brood larvæ entered at calyx as against 50.45 per cent of second-brood larvæ. On Plat II (demonstration) 20.95 per cent of first-brood larvæ entered at calyx end as compared with 0.52 per cent of second-brood larvæ, while on Plat III (one spray) 7.38 per cent of first-brood larvæ entered at calyx and 1.30 per cent of second-brood larvæ entered at this place.

Attention should also be called to the ratio of increase of larvæ between the first and second broods. On Plat I (unsprayed) for every larva of the first brood there were 1.82 second-brood larvæ, whereas on Plat II (demonstration) and Plat III (one spray) for each larva of the first brood there were 7.7 and 10.5, respectively, of the second brood.

Similar comparison may also be made from the data from Arkansas. Thus, on the unsprayed plat (V) for each first-brood larva there were 4.8 second-brood larvæ. On Plat III (one spray) for each larva of the first brood there were 105.6 larvæ of the second brood. Plat I (one-spray method) shows for each first-brood larva 121.5 second-brood larvæ.

To show the comparative efficiency of the demonstation and one-spray treatments in preventing infestation at calyx, side, and stem, Table XXII is presented.

TABLE XXII.—*Efficiency of the one-spray and demonstration treatments as shown by the percentage of wormy apples. Saugatuck, Mich., 1909.*

Plat No.	Percentage of wormy apples.[a]				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		
I. Unsprayed	13.98	7.67	0.62	22.20	8,409	37,875
II. Demonstration	.09	2.92	.01	2.33	998	42,818
III. Onespray	.13	7.05	.09	6.36	2,738	42,867

[a] Each entrance was counted in determining the percentages for calyx, side, and stem, so that the sum of these percentages exceeds the total percentage of wormy fruit.

It is here seen that the two methods of spraying were about equally effective in preventing entrance at the calyx, and that the one-spray method had practically no effect upon side entrance. The demonstration treatment saved a total of 4.03 per cent of the crop more than the one-spray, practically all of this saving being due to the prevention of side entrance. But, as in all the other experiments, the demonstration treatment failed to reduce side entrance to anything like the same degree that calyx entrance was prevented.

THE PLUM CURCULIO.

The effects of the applications of sprays on the plum curculio in the E. H. House orchard are shown in Table XXIII.

TABLE XXIII.—*Injury by the plum curculio for entire season, Plats I, II, and III. Saugatuck, Mich., 1909.*

PLAT I. UNSPRAYED.

	Number of punctured and sound apples, etc., per tree in each plat.						
	Tree 1.	Tree 3.	Tree 4.	Tree 7.	Tree 9.	Tree 10.	Tree 13.
No. punctures	1,452	422	506	505	1,078	756	141
No. fruit punctured	866	214	220	241	480	372	56
No. sound fruit	3,793	5,571	3,332	1,265	2,271	3,511	2,573
No. fruit	4,659	5,785	3,552	1,506	2,751	3,883	2,629
Per cent free from injury	81.41	96.30	93.81	83.99	82.55	90.42	97.87

TABLE XXIII.—*Injury by the plum curculio for entire season, Plats I, II, and III. Saugatuck, Mich., 1909*—Continued.

PLAT I. UNSPRAYED—Continued.

	Number of punctured and sound apples, etc., per tree in each plat.						Total per cent fruit free from injury.
	Tree 16.	Tree 20.	Tree 21.	Tree 26.	Tree 33.	Total for plat.	
No. punctures	1,108	883	530	1,265	1,197	9,843	....
No. fruit punctured	454	426	329	644	462	4,764	....
No. sound fruit	2,361	2,857	1,351	2,718	1,508	33,111	....
No. fruit	2,815	3,283	1,680	3,362	1,970	37,875	....
Per cent free from injury	83.87	86.96	80.42	80.85	76.55	....	87.42

PLAT II. DEMONSTRATION.

	Number of punctured and sound apples, etc., per tree in each plat.						
	Tree 101.	Tree 102.	Tree 105.	Tree 106.	Tree 108.	Tree 115.	Tree 117.
No. punctures	24	37	32	128	169	12	102
No. fruit punctured	11	13	15	60	61	5	62
No. sound fruit	1,614	1,752	2,145	1,790	5,658	4,017	5,734
No. fruit	1,625	1,765	2,160	1,850	5,719	4,022	5,796
Per cent free from injury	99.38	99.26	99.31	96.76	98.93	99.88	98.93

	Number of punctured and sound apples, etc., per tree in each plat.						Total per cent fruit free from injury.
	Tree 118.	Tree 127.	Tree 132.	Tree 135.	Tree 136.	Total for plat.	
No. punctures	112	89	139	398	10	1,252	....
No. fruit punctured	32	50	58	153	3	523	....
No. sound fruit	5,181	4,377	4,240	4,070	1,717	42,295	....
No. fruit	5,213	4,427	4,298	4,223	1,720	42,818	....
Per cent free from injury	99.39	98.87	98.65	96.38	99.83	....	98.77

PLAT III. ONE SPRAY.

	Number of punctured and sound apples, etc., per tree in each plat.						
	Tree 224.	Tree 225.	Tree 232.	Tree 236.	Tree 237.	Tree 238.	Tree 239.
No. punctures	1,015	278	108	198	64	67	45
No. fruit punctured	374	117	35	85	30	33	19
No. sound fruit	3,239	4,588	3,422	3,011	2,867	3,518	3,105
No. fruit	3,613	4,705	3,457	3,096	2,897	3,551	3,124
Per cent free from injury	89.92	97.51	98.99	97.25	98.96	99.07	99.39

	Number of punctured and sound apples, etc., per tree in each plat.							Total per cent fruit free from injury.
	Tree 244.	Tree 245.	Tree 246.	Tree 249.	Tree 252.	Tree 266.	Total for plat.	
No. punctures	228	255	238	194	42	143	2,875	....
No. fruit punctured	65	102	91	43	20	40	1,054	....
No. sound fruit	4,494	4,239	2,817	3,400	1,118	1,995	41,813	....
No. fruit	4,559	4,341	2,908	3,443	1,138	2,035	42,867	....
Per cent free from injury	98.57	97.65	96.87	98.75	98.24	98.03	....	97.54

The plum curculio, it will also be noted, was not especially destructive at Saugatuck, Mich., during the season of 1909, the unsprayed trees showing 87.42 per cent of fruit free from injury. Nevertheless the demonstration and one-spray plats show a fair benefit, but the difference in the amount of fruit free from injury between these two plats, namely, 1.23 per cent, is not important.

SUMMARY STATEMENT OF RESULTS.

For the purpose of more ready comparison, the percentages of fruit free from codling-moth and plum-curculio injury on the one-spray, demonstration, and unsprayed plats, from the several localities, are tabulated in Table XXIV. The average percentage of fruit free from these insects for the four orchards gives for the one-spray method 91.46 per cent as against 96.57 per cent for the demonstration treatment, a gain in favor of the latter of 5.11 per cent. Comparing the final average of percentage of fruit free from the plum curculio, there is seen to be a gain in favor of the demonstration treatment of 6.27 per cent.

TABLE XXIV.—*Percentages of fruit free from injury by the codling moth and plum curculio on one-spray, demonstration, and unsprayed plats in Arkansas, Virginia, and Michigan, in 1909.*

Locality.	Codling moth.			Plum curculio.		
	One spray.	Demonstration.	Unsprayed.	One spray.	Demonstration.	Unsprayed.
Siloam Springs, Ark	92.76	98.12	66.74	86.34	82.88	8.85
Crozet, Va	84.07	94.13	53.02	73.93	86.89	54.02
Mount Jackson, Va	91.68	92.74	54.00	57.90	40.82	27.23
Saugatuck, Mich	93.61	97.66	77.79	97.54	98.77	87.42
Average of four localities	91.46	96.57	65.14	77.10	83.37	49.17

Table XXV presents in comparison the effect of treatments for the four orchards in reducing the number of wormy apples. The table shows, besides the total efficiency, the protection afforded to each of the different parts of the apple. From the averages of the four localities it will be seen that approximately two-thirds of the total larvæ on the unsprayed plat entered through the calyx, while on the sprayed plats over three-fourths of the worms entered the fruit by way of the side. This shows the very much greater efficiency of the poison in the calyx than of that on the side of the fruit and emphasizes the twofold advantage of a thorough poisoning of the calyx, as there it is that the spray gives the greatest protection against the greatest number of larvæ. A comparison of the effects of the one-spray and demonstration treatments on the percentage of apples wormy at the calyx shows about an equal degree of protection by the two methods, the average for the demonstration treatment being slightly the better. As to side entrance, the one-spray gave little improvement over the unsprayed condition, while the demonstration showed a considerable reduction. Both methods were effective in reducing entrance at the stem end, the demonstration somewhat the more so.

TABLE XXV.—*Efficiency of the one-spray and demonstration treatments, as shown by the percentages of wormy apples, Arkansas, Virginia, and Michigan, 1909.*

Locality.	Percentage of wormy apples.											
	Calyx.			Side.			Stem.			Total.		
	One-spray.	Demonstration.	Unsprayed.	One-spray.	Demonstration.	Unsprayed.	One-spray.	Demonstration.	Unsprayed.	One-spray.	Demonstration.	Unsprayed.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Siloam Springs, Ark.	1.18	1.03	26.85	5.54	0.79	5.36	0.64	0.20	1.46	7.24	1.88	33.26
Crozet, Va.	.73	.45	23.67	14.28	5.02	17.82	.92	.40	5.49	15.93	5.87	46.98
Mount Jackson, Va.	.75	.99	35.71	6.46	5.61	7.48	1.11	.66	2.81	8.32	7.26	46.00
Saugatuck, Mich.[a]	.13	.09	13.98	7.05	2.92	7.67	.09	.01	.62	6.36	2.33	22.20
Average	.68	.57	23.85	7.64	2.87	8.92	.59	.18	2.21	8.55	3.42	34.86

[a] The figures under calyx, side, and stem for Saugatuck are based on the number of entrance holes instead of the number of apples entered.

CONCLUSIONS.

From the data presented, covering one season's work in three States, it appears that very satisfactory results may be obtained by the one-spray method, in so far as the control of the codling moth and plum curculio is concerned, although further experimentation will be necessary before final conclusions can be reached. Sight must not be lost, however, of the fact of the necessity, under eastern conditions, of making applications of Bordeaux mixture or other fungicide for the control of fungous diseases; so that in effect the one-spray method under present practices can not be recommended to orchardists in regions where fungous troubles, such as apple scab, apple fruit blotch, bitter rot, and leaf-spot affections require treatment.

The results, however, show the great importance of very thorough spraying to fill the calyx cups with poison. The efficiency of the spray at this point is much greater than at any other part of the apple. This, taken in connection with the fact that the majority of the larvæ seek the calyx as a point of entrance, makes the filling of the calyx of prime importance. Although the importance of accomplishing this has long been recognized by entomologists and fruit growers, it would appear that this work has not been done with sufficient thoroughness in the past, and eastern apple growers could certainly with great profit give more attention to thoroughness in the first spraying for the codling moth, immediately after the falling of the petals. The russeting of the fruit following such drenching applications of Bordeaux mixture, in which the arsenical has been generally applied, may doubtless be avoided by the substitution as a fungicide of dilute or self-boiled lime-sulphur wash, as shown to be feasible by Mr. W. M. Scott, of the Bureau of Plant Industry.

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

TESTS OF SPRAYS AGAINST THE EUROPEAN FRUIT LECANIUM AND THE EUROPEAN PEAR SCALE.

BY

P. R. JONES,

Engaged in Deciduous Fruit Insect Investigations.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

TESTS OF SPRAYS AGAINST THE EUROPEAN FRUIT LECANIUM AND THE EUROPEAN PEAR SCALE.

By P. R. Jones,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

Attention appears to have been first called in California to the brown apricot scale by Mr. Alex. Craw[a] in 1891, at which time the insect was described by him under the name *Lecanium armeniacum*. The investigations of Mr. J. G. Sanders[b] while an agent of this Bureau, however, have unmistakably shown that the brown apricot scale of California is identical with *Lecanium corni* Bouché, known in Europe since 1844, which Mr. Sanders has appropriately named "the European fruit Lecanium."

The European pear scale (*Epidiaspis pyricola* Del Guer.) was first recorded as occurring in the United States by Prof. J. H. Comstock[c] in 1883, from Sacramento, Cal., under the preoccupied name *Diaspis ostreæformis*. Since their introduction these two scale pests have been the subject of considerable attention on account of their injuries, and at the present time in the Santa Clara Valley are by far the most important scale insects with which orchardists have to contend. The European fruit Lecanium is now especially abundant and the copious honeydew excreted by the scales upon the leaves and fruit, with the accompanying sooty fungus, leaves the fruit in an unsightly condition for market.

In connection with other work in the deciduous fruit insect investigations of the Bureau of Entomology, carried on at the laboratory at San Jose, Cal., experiments have been made to determine an effective treatment for both of these insects, with the results recorded in the following pages. The work during 1908 was carried out by Messrs. Dudley Moulton and Chas. T. Paine.

[a] Rept. Cal. State Bd. Hort., p. 12, 1891.
[b] Journ. Econ. Ent., vol. 2, p. 443, 1909.
[c] 2d Rept. Ent. Dept. Cornell Univ., p. 94, 1883.

THE EUROPEAN FRUIT LECANIUM.

(*Lecanium corni* Bouché.)

APPEARANCE OF THE INSECT.

The insect heretofore generally known as the brown apricot scale belongs to the subfamily of scale insects, the Lecaniinæ, being naked but with hardened derm, and differs from the San Jose scale and European pear scale in that the horny covering of the full grown scale is a part of the body of the insect, while in the case of the other species mentioned the body is protected by a waxy covering made up from secretions and the molted skins of the larvæ.

The adult female of the European fruit Lecanium is about one-eighth to three-sixteenths of an inch long, three-thirty-seconds to one-eighth of an inch wide, and about one-eighth of an inch high, yellowish in color, marked with black. The older scales are shiny, oval, convex, and often covered with a mealy pruinose deposit (see Pl. XII, fig. 1).

PLAN OF WORK AND METHOD OF ASCERTAINING RESULTS.

In the winter of 1909 an infested orchard near San Jose, Cal., was selected and divided into 9 different plats of 14 trees each. Eight plats were used for trying out various sprays, and the ninth plat was left unsprayed for a check.

It was planned to examine a number of twigs at intervals of two days, two weeks, five weeks, three months, and ten months from date of spraying for proportion of live and dead scales; also, to take into account the action of the different washes on the trees and to examine the fruit as to freedom from the sooty fungus. The effect of the sprays upon the growth of lichens on the trunk and limbs was also to be noted. Such a number of examinations was considered necessary as some of the sprays were immediate in their action while others acted over a longer period.

APPLICATION OF SPRAYS.

All of the plats were treated February 18 with the sprays indicated below, using a single bent-disk nozzle (with one-eighth inch hole in disk) on each rod, the pressure being maintained at about 200 pounds by means of a gasoline-power outfit. At this pressure the lichens were thoroughly soaked. From 4 to 5 gallons of liquid were used per tree and the work was very thoroughly done.

SPRAYS USED AND METHOD OF PREPARATION.

Plat 1, 6 per cent distillate-oil emulsion.—This was made after the formula given in Bulletin 80, Part IV, Bureau of Entomology. A concentrated emulsion was made by dissolving 30 pounds of fish-

FIG. 1.—THE EUROPEAN FRUIT LECANIUM (LECANIUM CORNI BOUCHÉ) ON PECAN. (ORIGINAL.)

FIG. 2.—THE EUROPEAN PEAR SCALE (EPIDIASPIS PYRICOLA DEL GUER.) ON PEAR. (ORIGINAL.)

oil soap in 12 gallons of hot water and pouring the mixture into the spray tank with 20 gallons of distillate oil (28° Baumé). The mixture was then thoroughly agitated and run through the nozzles into a barrel at about 150 to 180 pounds pressure, giving a thick, creamy emulsion of about 55 per cent strength of oil. A powerful agitation, such as obtained by driving the liquid through nozzles or the relief valve at a high pressure, seems to be the most important factor in obtaining a stable emulsion. The formula used for the stock emulsion was:

Hot water .... gallons..	12
Fish-oil soap .... pounds..	30
Distillate oil (28° Baumé) .... gallons..	20

The fish-oil soap was made as follows:

Water .... gallons..	6
Lye .... pounds..	2
Fish oil .... gallons..	1½

The soap ingredients were boiled for about two hours and gave about 40 pounds of soap.

The 6 per cent distillate emulsion was made by taking about 5½ gallons of the concentrated emulsion and 44½ gallons of water. One pound of caustic soda was used to soften the water.

Plat 2, 5 per cent distillate-oil emulsion and caustic soda.—This was prepared by using 4½ gallons of the concentrated or stock emulsion, 5 pounds of caustic soda, and 45½ gallons of water to make 50 gallons of spray.

Plat 3, 6 per cent distillate-oil mechanical emulsion.—Made by using 3 gallons of distillate oil (28° Baumé), 1 pound of caustic soda, and 47 gallons of water to make 50 gallons of the liquid. This was agitated violently for about five minutes before being applied.

Plat 4, caustic soda.—Six pounds of caustic soda were used to 50 gallons of water.

Plat 5, 12 per cent crude-oil emulsion.—The formula used for this emulsion was—

Fish-oil soap .... pounds..	5
Lye .... do....	1
Crude oil .... gallons..	6
Water .... do....	43

This formula makes 50 gallons of liquid. The soap was dissolved in about 10 gallons of hot water; the soap water was then poured into the tank and the rest of the 43 gallons added; then the 1 pound of lye was added and the crude oil poured in slowly while the mixture was being agitated. *More water should never be added after the oil has been poured in.* The crude oil used was pure "Coalinga special" crude petroleum 16° to 22° Baumé, with an asphalt base.

Plat 6, resin-soda wash.—The following formula was used:

Resin	pounds	10
Caustic soda	do	3
Fish oil	do	$1\frac{1}{2}$
Water	gallons	50

The resin was broken into small lumps and together with the caustic soda placed in a kettle with 10 gallons of water. The mixture was then boiled for about half an hour, and while boiling $1\frac{1}{2}$ pounds of fish oil were added; it was then poured into the tank and diluted with sufficient water to make 50 gallons of the wash.

Plat 7, commercial lime-sulphur solution (1–8).—Six and one-fourth gallons of the concentrated lime-sulphur solution and $43\frac{3}{4}$ gallons of water were used to make 50 gallons of spray.

Plat 8, borax.—Ten pounds of borax were used in 50 gallons of water.

Plat 9.—For purposes of comparison this plat was left unsprayed.

The respective treatments and results of same are shown in the following table:

TABLE I.—*Results of spraying for the European fruit Lecanium, San Jose, Cal., 1909.*

Plat No.	Treatment.	Date sprays applied.	Number trees sprayed.	First examination, Feb. 22, 1909.			Second examination, Mar. 6, 1909.		
				Number scales examined.	Number dead scales.	Percentage of dead scales.	Number scales examined.	Number dead scales.	Percentage of dead scales.
1	Distillate-oil emulsion	Feb. 18	14	305	304	99	926	896	96
2	Distillate-oil emulsion and caustic soda	do	14	428	426	99	647	640	97
3	Distillate-oil emulsion, mechanical mixture	do	14	467	465	99	216	118	54
4	Caustic soda	do	14	100	98	98	194	179	92
5	Crude-oil emulsion	do	14	90	90	100	122	78	64
6	Resin wash	do	14	180	180	100	30	21	70
7	Commercial lime-sulphur wash No. 1	do	14	400	400	100	252	17	7
8	Borax	do	14	200	200	100	64	28	44
9	Check	do	14	325	14	4	739	71	9

Plat No.	Treatment.	Third examination, Mar. 26, 1909.			Fourth examinaton, July 1, 1909.	Fifth examination, Dec. 13, 1909.
		Number scales examined.	Number dead scales.	Percentage of dead scales.		
1	Distillate-oil emulsion	290	290	100	Scales all dead; lichens dead.	Scales all dead; lichens dead.
2	Distillate-oil emulsion and caustic soda.	234	234	100	do	Do.
3	Distillate-oil emulsion, mechanical mixture.	219	219	100	do	Do.
4	Caustic soda	65	61	94	do	Do.
5	Crude-oil emulsion	94	94	100	do	Do.
6	Resin wash	65	54	83	A few live scales	Do.
7	Commercial lime-sulphur wash No. 1.	248	44	15	A number of live scales; lichens dead.	A number of live scales; lichens dead.
8	Borax	107	31	29	do	Do.
9	Check	142	24	17	Scales nearly all alive; lichens flourishing.	Scales nearly all alive; lichens flourishing.

RESULTS.

It will be seen from Table I that nearly all of the washes showed lower percentages of dead scales at the time of the second examination than at the first, third, fourth, and fifth examinations. The first five washes gave excellent results in the percentage of scales killed, and cleaned the trees from lichens.

Lime-sulphur wash and borax gave apparently excellent results upon the first examination, but later examinations proved these washes to be of little value, and the trees at the end of the season appeared little better than the unsprayed trees.

The fruit (12 tons) from the 8 sprayed blocks was free from the smut fungus, while that from the unsprayed trees was quite black in appearance. Caustic soda, borax, lime-sulphur, and the resin wash were all caustic and immediate in their action on the insects. The distillate sprays were prompt in their action, but not so much so as the former. The crude-petroleum sprays gave more of a smothering effect, and were slower, their action extending over a long period.

None of the washes injured the trees seriously, but the caustic soda, resin, lime-sulphur, and borax sprays blackened the buds and hardened the bark to some extent.

The distillate and crude-oil sprays did not injure the buds or the bark of the trees in the least, although some of the buds were very far advanced at the time of application.

It was noted during the summer that the distillate and crude-oil emulsions seemed to possess fungicidal properties. On sprayed apricots and prunes, the foliage was dark and healthy and of much better color than on the unsprayed blocks.

THE EUROPEAN PEAR SCALE.

(*Epidiaspis pyricola* Del Guer.)

APPEARANCE OF INSECT AND EXTENT OF INJURY.[a]

The European fruit scale, or, as it is commonly known in California, the Italian pear scale, closely resembles to the naked eye the San Jose scale (*Aspidiotus perniciosus* Comst.), but can be readily distinguished from this species by the form of the male scale which is a great deal longer and carinated. (See Pl. XII, fig. 2.)

Furthermore, they can be separated by the manner of working. The European pear scale, in California, so far as the writer has observed,

[a] Comparatively little has been written in an economic way concerning this insect, either in this country or in Europe. The writer has been unable to find an account of its life history; probably because it has never proved so serious as some of the other scales injurious to fruit trees. Attention, however, is called to an article on the synonymy of the species by C. L. Marlatt in Entomological News, November, 1900, p. 590.

works only under cover of the lichens on the trunk and larger limbs, and apparently does not work on the twigs or younger branches as does the San Jose scale. While the European pear scale is not so serious a pest to fruit trees as is the San Jose scale, nevertheless its manner of working under lichens causes it to be neglected by fruit growers until the trees are badly infested, with consequent loss in vitality.

SPRAYING EXPERIMENTS IN 1908.

PLAN OF WORK AND MANNER OF APPLICATION.

An orchard badly infested with the European pear scale (see Pl. XIII) was selected in February, 1908, and divided into 16 plats of 6 to 16 trees each. It was planned to examine a large number of scales in the laboratory from the treated trees of each plat, and a like number from the unsprayed, or check, trees, and also to make field examinations as to the effect of the sprays on the scales, on the lichens, and on the trees.

The applications of sprays were made February 18, 19, and 20 on plats 1 to 12; and March 3, on plats 13 to 16. A strong hand-pump tank outfit and also a barrel pump were used. No pressure gauge was on the pumps, but pressure was probably not more than 60 to 75 pounds. Vermorel nozzles were used.

SPRAYS USED AND METHOD OF PREPARATION.

Plat 1, lime-sulphur wash.—This was made after the same formula described for the European fruit Lecanium.

Plat 2, commercial lime-sulphur solution No. 1.—The stock solution was used at the rate of 1 part to 9 parts of water.

Plat 3, commercial lime-sulphur solution No. 2.—This spray, of different brand, was used at same strength as preceding.

Plat 4, commercial 4 per cent distillate-oil emulsion.—This was used as follows:

Distillate-oil emulsion	gallons	$3\frac{1}{2}$
Caustic soda	pound	$\frac{3}{4}$
Water	gallons	50

Plat 5a, home-made 10 per cent distillate-oil emulsion.—This was made according to the following formula:

Boiling water	gallons	5
Fish-oil soap	pounds	2
Caustic soda	do	$\frac{3}{4}$
Distillate (28° Baumé)	gallons	5

When the water started to boil, the caustic soda was added; then the soap, and finally the oil. The whole mixture was then forced through a pump to emulsify it; it was then poured into the barrel and necessary water (40 gallons) to make 50 gallons of the spray was added.

VIEW OF PRUNE ORCHARD USED IN EXPERIMENTS AGAINST THE EUROPEAN PEAR SCALE. (ORIGINAL.)

A perfect emulsion was not formed, as some of the oil came to the top.

Plat 5b, 10 per cent distillate-oil emulsion.—This was made as follows:

Boiling water	gallons..	5
Fish-oil soap	pounds..	1½
Distillate (28° Baumé)	gallons..	5

Water (40 gallons) was added to make 50 gallons of the mixture. The emulsion was imperfect.

Plat 6, creosote-oil emulsion.—This is a commercial preparation and recommended to be used at the rate of 1 part to 20 parts of water, but was used 3 parts to 20 of water.

Plat 7a, home-made 10 per cent creosote-oil emulsion.—The following formula was used:

Boiling water	gallons..	5
Fish-oil soap	pounds..	2
Caustic soda	do....	2
Creosote oil	gallons..	5

The caustic soda, soap, and oil were added in turn after the water started to boil, and the mixture was forced through the pump to emulsify it. Water (40 gallons) was then added to make 50 gallons of wash.

Plat 7b, 5 per cent creosote-oil emulsion.—This was made in the same manner as for plat *7a*, except that 100 gallons of spray were made.

Plat 8, commercial carbolic emulsion (distillate).—The following formula was used:

Emulsion	gallons..	5
Water	do....	40

Plat 9, 10 per cent crude-oil emulsion.—This was made with the ingredients proportioned as follows:

Boiling water	gallons..	5
Caustic soda	pound..	¼
Fish-oil soap	pounds..	4
Crude oil (12° to 14° Baumé)	gallons..	5

The caustic soda, soap, and oil were added to the water, in turn, as soon as it had started to boil. The mixture was then forced through the pump twice to emulsify it. Water (40 gallons) to make 50 gallons of wash was then added. The emulsion was not perfect, as some free oil came to the top.

Plat 10, caustic soda.—The following formula was used:

Water	gallons..	50
Caustic soda	pounds..	4

Plat 11a, 12 per cent crude-oil emulsion.—The formula was as follows:

Boiling water.......gallons..	10
Fish-oil soap.......pounds..	2½
Lye.......do....	½
Crude oil (16° to 22° Baumé).......gallons..	3

The soap and lye were dissolved in the water, which was then placed in a barrel; 22 gallons of water were then added and the oil slowly poured in, and the mixture was thoroughly stirred. A very good emulsion resulted.

Plat 11b, 12 per cent crude-oil emulsion.—Same as for plat 11*a*, except that a "kerosene soap" was used.

Plat 11c, 12 per cent crude-oil emulsion.—Same as 11*a*, except that a 14° Baumé crude oil was used.

Plat 11d, 12 per cent crude-oil emulsion.—Same as 11*a*, except that a 12° to 14° Baumé crude oil was used.

None of the emulsions for plat 11 was forced through the pumps; but, on the other hand, no water was added to the mixture after the oil had been poured in. It seems to be essential, in order to keep free oil from coming to the top, that this be avoided. A good emulsion resulted in each case. The difference in gravity did not seem to make much difference in the emulsions, but the 16° to 22° Baumé, which was a "Coalinga special," appeared to give the best emulsion. All of the crude oils used contained an asphalt base.

RESULTS.

The results of the several sprays are given in Table II.

TABLE II.—*Results of spraying for the European pear scale, San Jose, Cal., 1908.*

Plat No.	Treatment.	Date sprays applied.	Number trees sprayed.	First examination, Mar. 3, 1908. Number scales examined.	Number scales dead.	Percentage of dead scales.
1	Lime-sulphur (homemade)	Feb. 18	16	1,172	1,000	85
2	Commercial lime-sulphur, No. 1	...do....	9	547	51	9
3	Commercial lime-sulphur, No. 2	...do....	13	838	581	69
4	Commercial distillate-oil emulsion	...do....	13	926	280	30
5*a*	Distillate-oil emulsion (homemade)	Feb. 19	7	834	285	34
5*b*	.....do	...do....	8	1,042	364	34
6	Commercial creosote-oil emulsion	...do....	11	664	174	26
7*a*	Creosote-oil emulsion (homemade)	Feb. 20	8	995	424	42
7*b*	.....do	...do....	11	854	780	91
8	Commercial carbolic-distillate emulsion	...do....	13	789	689	87
9	Crude-oil emulsion	...do....	12	1,177	480	40
10	Caustic soda	...do....	6	905	632	64
11*a*	Crude-oil emulsion	Mar. 3	6	....	....	....
11*b*	.....do	...do....	6	....	....	....
11*c*	.....do	...do....	6	....	....	....
11*d*	.....do	...do....	6	....	....	....

TABLE II.—*Results of spraying for the European pear scale, San Jose, Cal., 1908*—Con.

Plat No.	Treatment.	Second examination, Mar. 21, 1908. Number scales examined.	Number scales dead.	Percentage of dead scales.	Remarks.	Third examination, Dec. 17, 1908.
1	Lime-sulphur (homemade).	1,000	828	82	....	Many scales living; lichens mostly dead.
2	Commercial lime-sulphur, No. 1.	492	51	10	....	Many scales living; only larger lichens dead.
3	Commercial lime-sulphur, No. 2.	838	581	70	Scale killed better where there is heavy incrustation.	Do.
4	Commercial distillate-oil emulsion.	646	280	43	Lichens not all killed..	Many scales living; no lichens killed.
5*a*	Distillate oil emulsion (homemade).	549	285	52	.....do..........	Do.
5*b*	.....do..........	678	364	53	.....do..........	Do.
6	Commercial creosote-oil emulsion.	490	174	35	.....do..........	Many scales living; lichens mostly living.
7*a*	Creosote-oil emulsion (homemade).	571	424	74	Lichens all killed; bark hard and injured.	Many scales living; lichens mostly dead.
7*b*	.....do..........	854	780	91	Lichens all killed......	Do.
8	Commercial carbolic-distillate emulsion.	789	689	87	.....do..........	Do.
9	Crude-oil emulsion.....	697	480	69	.....do..........	Most all scales dead; lichens mostly all dead.
10	Caustic soda..........	905	632	64	Lichens all killed; bark hard.	Most all scales living; lichens mostly all dead.
11*a*	Crude-oil emulsion.....	(*a*)	(*b*)	100	.....do..........	Most all scales dead; lichens mostly all dead.
11*b*	.....do..........	(*a*)	(*b*)	100	.....do..........	Do.
11*c*	.....do..........	(*a*)	(*b*)	100	.....do..........	Do.
11*d*	.....do..........	(*a*)	(*c*)	90	.....do..........	Do.
Check	Unsprayed..........	736	84	11	....	....

a Large number. *b* All. *c* Nearly all.

An examination of the table shows that at the end of the season only the crude-oil emulsions had proved adequate in killing all the scales and lichens. No injury to the trees was apparent except where the caustic soda and creosote-oil emulsion were used.

SPRAYING EXPERIMENTS IN 1909.

PLAN OF WORK AND MANNER OF APPLICATION.

A badly infested orchard other than the one used in 1908 was selected and divided into 6 different plats of 32 trees each. Four examinations of infested material were made in the laboratory and in the field at intervals of three days, three weeks, six weeks, and eight months, respectively, after the applications. A large number of scales was examined from each of the six plats and the check plat.

The applications were made March 1, 1909, with a strong power outfit, using two leads of hose with 12-foot bamboo rods and single-crook nozzles, with $\frac{1}{8}$-inch apertures. A pressure of 200 to 240 pounds was maintained, and the trees were given a very thorough treatment.

SPRAYS USED AND METHOD OF PREPARATION.

Plat 1, 6 per cent distillate oil (mechanical mixture).—This was prepared as follows:

Water	gallons..	90
Caustic soda	pounds..	2
Distillate oil (28° Baumé)	gallons..	6

The water was poured into the tank; then the caustic soda was added to soften the water, and the oil slowly poured in while the water was being violently agitated. The mixture was applied immediately.

Plat 2, caustic soda.—The formula was as follows:

Water	gallons..	100
Caustic soda	pounds..	16

Plat 3, crude-oil emulsion.—This was prepared as follows:

Water	gallons..	86
Fish-oil soap	pounds..	10
Lye	do....	2
Crude oil (16° to 22° Baumé)	gallons..	12

About 20 gallons of the water were heated, and when this began to boil the dissolved soap and then the lye were added. This mixture was then removed to the tank, and the rest of the water (66 gallons) added, making 86 gallons in all. The spray pump engine was then started and the crude oil slowly poured into the tank, the mixture being violently agitated by the tank agitator. A perfect emulsion resulted.

Plat 4, commercial lime-sulphur solution, No. 1.—The formula was as follows:

Water	gallons..	100
Commercial lime-sulphur	do....	11

Plat 5, borax.—The formula was as follows:

Water	gallons..	100
Borax	pounds..	20

The borax was dissolved in 30 gallons of hot water and poured into the tank, and the rest of the water added.

Plat 6, well-cooked lime-sulphur wash.—The proportions of ingredients were as follows:

Lime	pounds..	30
Sulphur	do....	30
Water	gallons..	100

This wash was made in the same manner as previously described.

The results of tests in 1909 are given in Table III.

TABLE III.—*Results of spraying for the European pear scale, San Jose, Cal., 1909.*

Plat No.	Treatment.	Date sprays applied.	Number trees sprayed.	First examination, Mar. 3-4, 1909.			Second examination, Mar. 20, 1909.			Remarks.
				Number scales examined.	Number scales dead.	Percentage of scales dead.	Number scales examined.	Number scales dead.	Percentage of scales dead.	
1	Distillate-oil mechanical mixture.	Mar. 1	32	620	516	83	498	380	78	Lichens mostly alive.
2	Caustic soda	...do....	32	706	534	75	844	749	88	Do.
3	Crude-oil emulsion	...do....	32	344	297	86	599	393	65	Lichens all dead.
4	Commercial lime-sulphur, No. 1.	...do....	32	950	846	89	709	627	88	Lichens mostly dead.
5	Borax	...do....	32	407	361	88	1,029	1,003	97	Do.
6	Homemade lime-sulphur.	...do....	32	371	275	74	673	504	74	Lichens nearly all alive.
7	Check	....	....	941	541	56	685	341	49	Lichens flourishing.

Plat No.	Treatment.	Third examination, Apr. 16, 1909.			Fourth examination, Nov. 20, 1909.			Remarks.
		Number scales examined.	Number scales dead.	Percentage of scales dead.	Number scales examined.	Number scales dead.	Percentage of scales dead.	
1	Distillate-oil mechanical mixture.	805	789	98	759	757	100	Lichens mostly dead; bark soft.
2	Caustic soda	637	449	70	455	449	98	Lichens mostly dead; bark hard.
3	Crude-oil emulsion	648	613	94	207	207	100	Lichens mostly dead; bark soft.
4	Commercial lime-sulphur, No. 1.	536	411	76	659	624	93	Lichens mostly dead; bark slightly hardened.
5	Borax	640	609	95	452	449	99	Lichens mostly dead; bark hard.
6	Homemade lime-sulphur.	652	514	79	1,147	811	70	Lichens mostly dead; bark slightly hardened.
7	Check	372	133	35	939	96	10	Lichens flourishing.

RESULTS.

An examination of Table III shows that all of the sprays with the exception of the commercial lime-sulphur solution No. 1 and the well-cooked lime-sulphur washes proved very successful in killing the scale. All of them killed most of the lichens. The caustic-soda and borax treatments injured the trees to a certain extent and hardened the bark. In the case of the trees treated with distillate-oil emulsion and crude-oil emulsion the bark was normal and in good condition.

As noted previously, on the apricots the distillate-oil sprays as well as those from crude oil seemed to possess distinct fungicidal properties, as the foliage was as dark and healthy on these plats and remained on the trees as long as on the plats sprayed with commercial and cooked lime-sulphur washes.

A comparison of the results of 1908 and 1909 shows much in favor of the latter year, which should be attributed to the better method of application and of making the sprays. It appears essential for good results to use a power outfit at a high pressure and a coarse drenching spray to penetrate the lichens and the heavy scale incrustation. A power sprayer is especially useful in applying distillate-oil emulsion, crude-oil emulsion, and mechanical mixtures of either, as a hand outfit does not give sufficient agitation for a perfect emulsion.

The writer recently noticed several prune orchards which had been sprayed with a commercial distillate spray and caustic soda at 4 per cent strength; they were well cleaned of the scales and lichens.

COST OF SPRAYING.

Table IV shows the comparative cost of materials of the most important and efficient treatments. To get the total cost of spraying it will be necessary merely to add the cost of the labor, which is variable and was therefore not included. Usually 3 men and a team are required for spraying with a hand pump and the same number with a power outfit, adding an additional man and team where a supply wagon is used.

The number of trees that can be sprayed in a day is variable, depending upon the size of the trees, the availability of the water, and the efficiency of the labor. With medium-sized prune trees, from 800 to 1,000 trees is considered a good day's work with a power outfit and a supply tank.

Below is shown what the ingredients of the spray mixtures would cost the fruit grower in the vicinity of San Jose in barrel lots:

Lime (unslaked)	per barrel	$1.75
Sulphur (flour)	per 100 pounds	2.65
Caustic soda, in 120-pound cases	per pound	.05½
Borax, in 12-pound cases		1.40
Lye, in 48-pound cases		3.25
Fish oil, in barrel lots	per gallon	.35
Crude oil (12 to 24° Baumé), in 110-gallon drums		3.00
Distillate oil (28° Baumé), in 110-gallon drums	per gallon	.07–.09
Commercial lime-sulphur solution	per barrel	[a] 10.00
Commercial distillate-oil emulsion	do	[a] 7.50
Commercial distillate emulsion and caustic soda	do	[a] 9.95

A good fish-oil soap can be made at the following cost:

Lye, 2 pounds	$0.1354
Fish oil, 1½ gallons	.5250
Water, 6 gallons.	

This makes $0.6604 for 40 pounds of soap, or $0.0165 per pound.

The concentrated distillate-oil emulsion (55 per cent) will cost:

Hot water, 12 gallons.	
Fish-oil soap, 30 pounds	$0.495
Distillate oil (28° Baumé), 20 gallons	1.400
Total	1.895

This makes $1.895 for 36 gallons, or $0.0526 per gallon.

[a] About.

Table IV.—*Comparative cost of spray materials.*

Treatment.	Formula. Article.	Formula. Quantity.	Cost of ingredients.	Cost per 100 gallons.	Cost per diluted gallon.	Cost per tree (prune).	Cost per tree (apricot).
6 per cent distillate oil (mechanical mixture).	Oil Caustic soda Water	6 gallons 2 pounds 94 gallons	$0.42 .11	$0.53	$0.0053	$0.0212	$0.0265
6 per cent distillate-oil emulsion.	Concentrated emulsion. Caustic soda Water	11 gallons 2 pounds 89 gallons	.5786 .11	.6886	.00688	.0275	.0344
5 per cent distillate-oil emulsion and caustic soda.	Concentrated emulsion. Caustic soda Water	9 gallons 10 pounds 91 gallons	.4734 .55	1.023	.0102	.0408	.0511
4 per cent commercial distillate-oil emulsion.	Emulsion Water	$6\frac{2}{3}$ gallons $92\frac{1}{3}$ gallons	1.00	1.00	.01	.04	.05
4 per cent commercial distillate-oil emulsion and caustic soda.	Emulsion Water	$6\frac{2}{3}$ gallons $92\frac{1}{3}$ gallons	1.326	1.326	.0132	.0528	.066
12 per cent crude-oil emulsion.	Oil Soap Lye Water	12 gallons 10 pounds 2 pounds 88 gallons	.3264 .0875 .1354	.5493	.0054	.0219	.0274
Resin-soda wash	Resin Caustic soda Fish oil Water	20 pounds 6 pounds 3 gallons 100 gallons	.55 .33 .1311	1.011	.0101	.0404	.0505
Commercial lime-sulphur No. 1 (1-8).	Concentrated solution. Water	11 gallons 88 gallons	2.20	2.20	.022	.088	.11
Home-made lime-sulphur.	Lime Sulphur Water	40 pounds 30 pounds 100 gallons	.35 .795	1.145	.0145	.058	.0725
Caustic soda	Caustic soda Water	12 pounds 100 gallons	.66	.66	.0066	.0264	.033
Borax	Borax Water	20 pounds 100 gallons	2.32	2.32	.0232	.0928	.116

SUMMARY.

Distillate-oil emulsion at 5 per cent and 6 per cent strengths, with and without caustic soda; crude-oil emulsion at 12 per cent strength; and resin-soda wash are effective in controlling the European fruit Lecanium and in cleaning up the trees from lichens and do not injure the trees when applied as a winter treatment.

Distillate-oil emulsion at 5 per cent and 6 per cent strengths, with and without caustic soda; distillate oil at 6 per cent strength (mechanical mixture); and crude-oil emulsion at 12 per cent strength are effective in controlling the European pear scale, destroy the lichens, and do not injure the trees when applied as a winter treatment.

Caustic-soda and creosote-oil emulsion sprays control both of these scales and destroy the lichens, but are injurious to the tree.

Lime-sulphur and borax sprays are not so efficient in controlling these scales, especially the European fruit Lecanium, as are the distillate-oil and crude-oil emulsions, and borax acts on the trees in the same way as does caustic soda.

Distillate-oil and crude-oil emulsions appear to have distinct fungicidal properties aside from their insecticidal value.

Distillate-oil emulsions at 6 per cent strength and crude-oil emulsion at 12 per cent strength, measured by their efficiency against scales and lichens, convenience of preparation and application, and cost, are the sprays best adapted for the European fruit Lecanium and the European pear scale.

The 6 per cent distillate-oil emulsion will cost about 2½ cents for each prune tree and 3½ cents for each apricot tree.

The 12 per cent crude-oil emulsion will cost about 2 cents for each prune tree and 2½ cents for each apricot tree.

All sprays, to insure the best results, should be applied with a power outfit at a high pressure (180 to 200 pounds). A coarse, drenching spray applied with crook nozzles is preferable, and February is the best month in which to spray.

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