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CODLING MOTH STUDIES NORTH FORK VALLEY OF COLORADO

By J. H. NEWTON

COLORADO STATE COLLEGE
COLORADO EXPERIMENT STATION
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OFFICE OF STATE ENTOMOLOGIST
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CODLING MOTH STUDIES NORTH FORK VALLEY OF COLORADO

By J. H. NEWTON[1]

Studies of the codling moth, *Carpocapsa pomonella L.*, in the North Fork Valley of Colorado have been conducted at Paonia for the past 16 years.[2] This project was outlined for the definite purpose of establishing correct spraying dates and practices that might prove to be most economical for the control of the codling moth in Delta County and similar apple-producing sections of the state. Certain results of the studies were given in Colorado Experiment Station Bulletin 268, 1921, Codling Moth Control for Certain Sections of Colorado. The data have been the basis of the control recommendations during the different years for many of the apple-growing sections of the state. This information has been given through special articles, growers' meetings, field meetings in the experimental orchards, and in various other ways. The problem has been and will continue to be a changing one but it is felt that a summary report with the present control recommendations should be given.

While the life-history data and control recommendations contained in this report apply primarily to Delta County, they are in a general way applicable to all other sections of Colorado with the possible exception of Mesa County, where the problem is more difficult and requires a separate consideration as reported in Colorado Experiment Station Bulletin 322 of 1927.

The North Fork Valley, with Paonia as the focal point, was selected because of its economic status in apple production in Colorado, and the apparent difference in the problem of codling-moth control in comparison with the Grand Valley District of Mesa County, where extensive studies had been made previous to 1917 by both federal and state departments.

Laboratory records of codling-moth emergence and egg deposition formed the basis for the timing of spray dates from 1917 to 1924. From 1924 to date, the laboratory work has been gradually supplemented by field methods, until at present the spraying dates are based entirely upon field notes of the moth flight as indicated by the number of moths trapped in the so-called "hooch-traps" or "bait-pails." Spray experiments for the

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1 Deputy State Entomologist. The studies of the codling moth and its control herein reported, were financed by funds from the Office of State Entomologist, Bureau of Plant and Insect Control.

2 Presented for publication April, 1934.

control of the codling moth were not attempted until a comprehensive understanding of the seasonal occurrence of the broods had been established by laboratory records and field notes.

Delta County As an Apple-Producing Unit of Colorado

Although Delta County ranks thirty-ninth in actual agricultural acreage of the state, it contains 41 percent of the fruit plantings and produces 32 percent of the total apple crop. The fruit areas of the county are made up of valleys and table lands or mesas, ranging in altitude from 4,980 feet above sea level to 6,100 feet at Cedaredge, or a variation of 1,120 feet in 25 miles of distance.

This variation of altitude, in combination with the various types of air and soil drainage, makes up a most intricate codling-moth habitat. Variation in the time of blooming throughout the county is more pronounced than the variation in the moth activity, which will be more clearly pointed out in the discussion of the moth-trap records. Climatic variations within the county are large as evidenced by an annual mean precipitation of approximately 8 inches at Delta and 14 inches at Paonia. Those orchards situated on the higher mesas are frequently subjected to local disturbances such as thunder showers which travel along the base of the continental divide. The temperature and humidity fluctuations accompanying such disturbances are directly reflected in the moth activity and therefore affect the results of control measures.

Definition of Terms

The four distinct stages or periods of development through which the insects pass are known as: Egg, larva, pupa and adult or moth.

The term "generation" is applied to include all four stages of a specific group originating from a common parentage.

The term "life cycle" denotes the period of time required to pass through the four stages from the egg to the emergence of the moth of the same generation.

Larvae that live over from one season to the next in hibernation are known as "non-transforming," "hibernating," or "over-wintering" larvae. Those that transform to pupae and adults the same season they hatch are known as "transforming larvae."

The spring-brood pupae are the first pupae of the year, coming from the over-wintering larvae.

The spring-brood moths are often spoken of as first-brood moths, but since they have developed from larvae of the previous season, it is more logical to speak of them as the spring-brood moths and consider the first generation to begin with the eggs.

The term "active" as active emergence is used to denote an increasing activity.

Seasonal History at Paonia

The percentage of first-brood larvae transforming to first-brood moths varies from season to season. In the North Fork Valley only 40 percent of the first-brood larvae normally transform to first-brood moths; the other 60 percent carry over as hibernating or non-transforming larvae to the following spring, when they emerge as spring-brood moths. At Austin more of the first-brood larvae (66 percent) transform than at the higher altitudes such as at Paonia and Cedaredge. This is largely responsible for the variation in the size of broods, and is directly responsible for the greater population of moths in the orchards at the lower altitudes.

The seasonal history of the codling moth in Delta County is briefly outlined by the following statements as to the broods and their sequence:

The First Generation.—a.—The over-wintering or hibernating larvae are the non-transforming larvae of the previous season.

b.—The first-brood eggs are the first eggs of the season, deposited by the spring-brood moths.

c.—The first-brood larvae hatch from the first-brood eggs and are the basis for need of the first-brood cover sprays.

d.—The first-brood pupae are in reality the second pupae of the year, but actually represent the first-brood pupae of the season.

e.—The first-brood moths emerge from first-brood pupae and are often spoken of as the summer-brood moths.

The Second Generation.—a.—The second-brood eggs are laid by the first-brood moths.

b.—The second-brood larvae hatch from second-brood eggs and are the basis for need of second-brood cover sprays. Ninety-eight percent of these are non-transforming, so carry over to the following spring. Only in rare instances of long-drawn-out, dry summers has there been an appearance of second-brood moths in the North Fork Valley.

Habits and Life Cycle

Hibernation.—The codling moths hibernate as mature larvae in silken cocoons underneath bark scales, in rubbish about the base of the tree or in tree crotches, in picking boxes, packing sheds, or any other similar place that will afford protection. Hibernating larvae are the non-transforming larvae of the first and second broods of the previous season. In the North Fork Valley approximately 60 percent of the first-brood larvae and nearly all of the second enter hibernation and carry over until the following spring. In the Austin-Cory District only 34 percent of the first-brood larvae are non-transforming.

The Moth.—The moth is three-eighths of an inch in length and one-quarter of an inch in width, when at rest with the wings along the back. The wing expanse varies from five-eighths to three-fourths of an inch. The female is slightly larger than the male. The predominate color is a silken grey, with the tips of the wings capped with a dark brown, over which there are broken lines of a golden hue. This tipping of the wings with brown and gold is a characteristic marking of the species. The comparatively small size of the moth and its irregular flight make it an inconspicuous individual even in a heavily infested orchard. The moths are most active at dusk and during the twilight of the evening when egg laying takes place. Normally the moths are not strong flyers, but they may drift with the wind during the active flight of the evening. In natural flight they follow a zig-zag course, making their path of flight difficult to follow with even the trained eye.

The Egg.—The egg is circular in outline, flat, and measures from 1 to 1.25 millimeters in diameter. A freshly laid egg is opaque to semi-transparent, resembling somewhat a minute drop of paraffin compressed to a thin layer. Two distinct stages in the embryonic development of the larva can be seen through the egg shell; the first being a distinct red ring, known as the "red-ring stage," and the second as the "black-spot stage," due to the black head shield of the nearly mature larva showing through the transparent shell.

The first eggs of the season are laid upon the surface of leaves, preferably upon the upper surfaces and near the fruit clusters. After the fruit has attained size, many are laid directly upon the fruit surface.

Growers often argue that the larva may enter the fruit directly beneath the egg shell; however, in studying large numbers of eggs in the laboratory, no evidence of this has been seen. In fact, the larva is coiled so tightly beneath the upper surface of the shell that it would be impossible to make entrance into the fruit without first breaking the upper layer. All hatched eggs show a distinct slit in the upper shell from which the larva has emerged. It is impossible for them to make entrance directly into the fruit beneath the egg. This point is presented to refute the idea that cover sprays should be applied before the eggs are laid.

Larva.—The newly hatched larva is one-sixteenth of an inch in length, of flesh color, with a dark brown head. The mature larva is three-quarters of an inch in length and of a similar color.

The newly hatched larvae often spend considerable time in crawling about, either in search of fruit or in seeking a favorable place to make entrance. As they crawl about they spin and leave behind a minute thread of silk which affords protection should they be suddenly dislodged. Newly hatched larvae are intent upon seeking a hiding place as they often seek shelter beneath the calyx lobes of the fruit, which undoubtedly is a protective habit to get away from natural enemies. Once within the calyx cavity, they find conditions which afford protection and ease of entrance. The same may be partially responsible for the entrance made where fruits touch. *It has often been observed that the newly hatched larvae spin a small amount of silken web for the purpose of gaining a foothold to aid in making entrance. Certain varieties of apples which have a tough skin are more easily protected by the arsenical sprays, because the larvae must spend more effort to gain entrance and in so doing are more likely to become poisoned. Many of the newly hatched larvae are poisoned upon the leaf surface before reaching the fruit.

Mature larvae leave the fruit and crawl down the limbs in search of hiding places to spin their cocoons in preparation for the pupal stage.

Cocoon and Pupa.—The insect transforms from larva to moth within a cocoon made up of silken threads and small bits of bark and other debris which may be available. Cocoons of the hibernating larvae are much heavier than those of the larvae that transform during the season. Hibernating larvae, in preparation for the emergence of the spring-brood moths, open the cocoons and construct exit tubes, the length depending upon the

*Hoerner, J. L., Journal of Economic Entomology, Vol. 18, Page 423, 1925.
*Smith, R. H., Hilgardia, Calif., Agri. Exp. Sta., Vol. 1, No. 17, 1926.
*Gilmer, Paul M., Journal of Kansas Entomological Society, Vol. 6, No. 1, Page 19, 1933.

position relative to a point of free emergence. In the spring activity, many over-wintering larvae move to an entirely new location and construct new cocoons.

The pupae are at first light yellow in color, becoming darker as they develop, until they are a mahogany brown just before moth emergence. The pupal stage is often spoken of as the "cigar stage" since it resembles, to a certain extent, the tubular shape and color of a cigar. Just before the moth emerges, rotary movements of the pupa cause it to move forward in the exit tube to a point where the moth can easily emerge. The brownish-colored pupal cases are often seen protruding from hiding places.

Eight Years of Laboratory Studies

From 1917 to 1924 inclusive, detailed laboratory studies were made of the life-cycle together with moth-emergence and egg-deposition activities of the moths. Material for the studies was obtained by gathering mature larvae from banded trees. These larvae were allowed to pupate in strips of corrugated cardboard which were placed in battery jars in an outdoor insectary, subjected to as nearly natural conditions as possible. Moth-emergence records were made by the daily removal of the newly emerged moths from the jars containing the hibernating or pupating larvae.

Methods Used in Life-History Studies

The newly emerged moths were placed in breeding cages to obtain egg-deposition records. The egg-deposition cages consisted of battery jars covered with cheese cloth and containing a layer of moist sand capped with a blue blotter to form the bottom of the cage. The moths were fed brown-sugar water by means of a moist sponge. From 2 to 25 moths were placed in each cage. Fresh pear leaves were introduced each day for the purpose of obtaining eggs for incubation records. Daily records of the egg deposition in each cage were made by counting the eggs upon the pear leaves and the sides and floor of the cage. The eggs deposited upon the leaves were removed with the leaves, while those on the sides and floor of the cage were destroyed by crushing with some blunt instrument as they were counted. Those upon the floor were easily counted as they were prominently visible against the blue blotter.

Egg-incubation records were obtained by the use of the freshly deposited eggs upon the pear leaves, which were placed in screen presses and held in cloth-covered battery jars. Daily records were made of the several stages of development. The development of the larvae from hatching to the time of leaving

Table 1.—Average and minimum days required for the development of the different stages of the codling moth. Paonia, Colorado, for the years 1917, 1918, 1919 and 1920.

	1917		1918		1919		1920	
	Av.	Min.	Av.	Min.	Av.	Min.	Av.	Min.
Pupation period of over-wintering larvae			24.88		23.84		22.3	
Time from emergence of first-brood moths until first eggs are laid			4.15	1	4.11	1	4.53	1
Incubation period of first-brood eggs			8.2	6	8.9	6	9.7	8
Feeding period of first-brood larvae			27.6	17	20.83	17	23.47	18
Time after first-brood larvae leave the apple until second-brood moths appear	17.46	12	22.84	17	16.69	12	18.85	16
Time from emergence of second-brood moths until first eggs are laid	2.1	1	2.65	1	1.69	1	2.87	1
Incubation period of second-brood eggs	8.1	6	9.9	9	7.8	6	9.1	6
Feeding period of second-brood larvae	32.9	22	34.1	22	27.68	16	35.06	23

the fruit was recorded from newly hatched larvae placed upon apples in cloth-covered battery jars. No attempt was made to record the instar stages of larval growth. In Table 2 is presented a summary of the laboratory moth emergence and egg deposition for seven first broods and eight second broods of the codling moth. This record aggregates 13,359 females and 14,275 male

Table 2.—Codling-moth oviposition in breeding cages. Paonia, Colorado, 1917 to 1924. (Summary)

	First brood				Second brood			
Season	Female moths	Male moths	Total eggs	Average per female	Female moths	Male moths	Total eggs	Average per female
1917	——	——	——	——	1,144	1,295	63,070	55.13
1918	2,250	2,610	52,402	23.28	1,847	2,310	63,023	34.12
1919	1,133	1,165	27,790	24.50	2,034	2,117	132,868	65.31
1920	795	634	13,663	17.19	472	513	18,040	37.22
1921	1,033	1,121	16,363	15.72	516	491	20,114	38.94
1922	174	208	3,578	20.56	184	198	5,491	29.29
1923	686	637	4,405	6.42	246	202	7,578	30.80
1924	693	668	11,770	16.98	152	106	7,404	48.71
Total	6,764	7,043	129,971	19.10	6,595	7,295	317,588	48.15

moths, from which 447,559 eggs were recorded. This is somewhat less than the actual number of emerged moths for some of them escaped in making up the cages.

Records of Seasonal History

Blooming Period and the Calyx-Spray Date.—

Year	Full bloom (Jonathan)	Calyx spray	Number of days from full bloom to calyx-spray date
1917	May 23	———	———
1918	May 9	May 24	15 days
1919	May 4	May 15	11 days
1920	May 20	May 31	11 days
1921	May 3	May 15	12 days
1922	May 15	May 24	9 days
1923	May 13	May 22	9 days
1924	———	May 24	———
1925	May 1	May 9	8 days
1926	May 4	May 17	13 days
1927	May 7	May 14	7 days
		Average	10.5 days

The blooming dates given above are taken from notes made of a Jonathan tree on Pitkin Mesa by Omar Wilson. In this record there is a variation of 22 days in the blooming period of a Jonathan apple in this locality. The average date of full bloom is May 12. The average number of days from full bloom to the calyx spray is approximately 10 days.

Spring-Brood Pupae.—Spring activity of the codling moth starts with the first warm days of April by the preparation of the over-wintering larvae for pupation. This preparation consists in the opening of the winter cocoon and the construction of an emergence tube to the surface of whatever object they may happen to be beneath. The pupal stage of the spring brood averages from 22 to 24 days, this being approximately 10 days longer than the pupal stage of the first-brood pupae during the month of June. This may be accounted for by the fact that the first warm days of early spring start pupation but is often retarded by cooler weather.

Spring-Brood Moths.—The time of emergence of the spring-brood moths depends upon the temperature. Twelve years of moth-emergence records show a variation of 19 days from the earliest moth to the latest date for the beginning of spring-brood

Table 3.—Laboratory and field notes of codling-moth activities with spray dates as established from 1917-1933. North Fork Valley, Paonia, Colo.

		First Brood							Second Brood					
Year	Full bloom	Calyx spray	First moth	Peak of moth emergence	First egg	Peak of egg deposition	First cover spray	Second cover spray	First moth	Peak of moth emergence	First egg	Peak of egg deposition	Third cover spray	Fourth cover spray
1917	May 23	—	—	—	—	—	—	—	July 19	Aug. 1-3	July 22	Aug. 9	Aug. 7	Aug. 23
1918	May 9	May 24	May 21	June 5	June 4	June 13	June 15	June 25	July 7	Aug. 2	July 14	July 29	Aug. 1	Aug. 17
1919	May 4	May 15	May 15	May 25	May 19	June 16	June 4	June 4	July 1	July 16-26	July 2	Aug. 3	July 19	Aug. 5
1920	May 20	May 31	May 26	June 5	June 2	June 12	June 14	June 24	July 16	July 28	July 20	Aug. 15	Aug. 7	Aug. 23
1921	May 3	May 15	May 13	May 29	May 24	June 12	June 5	June 15	July 13	July 23-27	July 15	Aug. 5	July 27	Aug. 13
1922	May 15	May 24	May 23	May 30	May 30	June 13	June 14	June 24	July 14	July 23-26	July 17	Aug. 4	July 29	Aug. 16
1923	May 13	May 22	May 24	May 29	May 30	June 12	June 14	June 24	July 20	July 29	July 24	Aug. 8	July 27	Aug. 13
1924	May —	May 24	May 17	May 24.31?	May 24	June 14	June 12	June 22	July 15	July 22-17	July 18	Aug. 9	July 31	Aug. 16

The above are laboratory records, while the following are taken from field notes on moth flight as recorded from catches made in "hooch" or bait traps.

Year	Full bloom	Calyx spray	First moth	Peak of moth emergence	First egg	Peak of egg deposition	First cover spray	Second cover spray	First moth	Peak of moth emergence	First egg	Peak of egg deposition	Third cover spray	Fourth cover spray
1925	May 1	May 9					June 5	June 15	July 15	July 20			July 22	Aug. 9
1926	May 4	May 17	May 11	May 22			June 2	June 12					July 28	Aug. 13
1927	May 7	May 14	May 15	May 21			June 2	June 12	July 28	Aug. 13			July 27	Aug. 11
1928	May —	May 19					June 4	June 14	July 18	July 26			July 23	Aug. 6
1929	May —	May 29	May 24	June 5			June 12	June 22	July 16	Aug. 9			July 24	Aug. 15
1930	May 3	May 15	May 15	May 27			June 5	June 15	July 20	July 28			July 22	Aug. 9
1931	May 5	May 17	May 12	May 31			June 6	June 16	July 15	July 22			July 22	Aug. 6
1932	May 6	May 16	May 17	May 29			June 8	June 18	July 19	Aug. 3			July 27	Aug. 12
1933	May 22	May 29	May 30	June 3			June 14	June 24	July 19	Aug. 26			July 26	Aug. 11

emergence. The earliest date of moth flight was May 11, 1926, and the latest date was May 30, 1923. See Table 3 and footnote.***

Spring-Brood Emergence.—It is difficult to locate the peak of moth emergence for a particular brood, due to the fact that there are usually several high points in each brood. In the spring brood the period of moth activity is shorter than in the first brood. The laboratory records at Paonia show an average of approximately 8 days from the time of the first moth emergence to the first egg deposition. The length of this period is varied by intermittent cool and inclement weather which also often interrupts the early emergence of the spring-brood moths. The average time required for the brood to reach active emergence is approximately 6 days. The mid-point of active moth emergence follows in 16 days. There is considerable variation in the period of time from the first moth to active egg laying. For the spring brood there is an average of 22 days of active moth emergence. The period of egg laying averages 47 days, of which 30 days represent very active egg deposition. These averages of moth activity govern directly the timing and application of sprays adopted in this report. The average length of life of the spring-brood moth is 10 days. During the first few days of emergence the moths are predominately males. In some instances females are not present for 3 or 4 days.

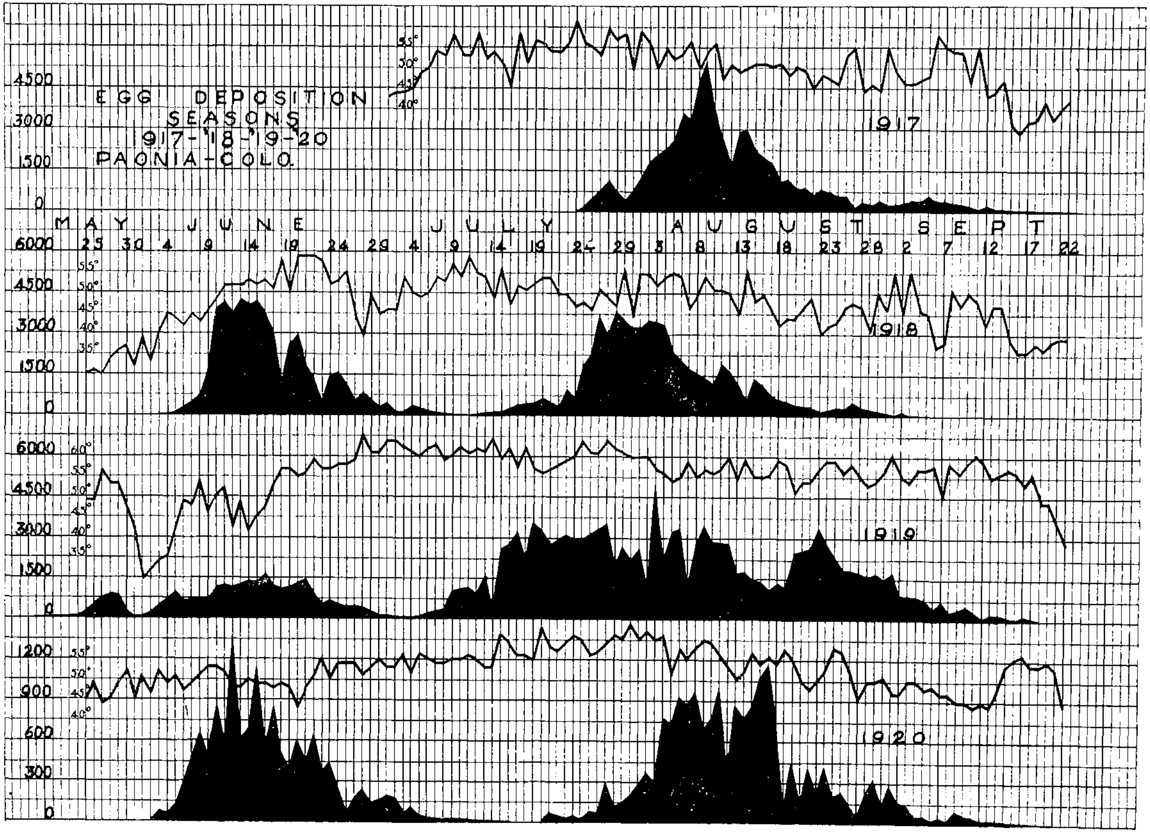
First Generation

First-Brood Eggs.—The first-brood eggs are laid by the spring-brood moths. The period of time from first emergence to active egg laying varies greatly, due to the fact that early spring temperatures directly affect this activity. Moths often emerge during favorable weather to have a cooler period delay egg laying. This is evident from Table 4, which shows an average of nearly 8 days from first moth to first egg with a minimum of 4 days and a maximum of 14 days. There is a correspondingly large variation in the dates of active egg laying as shown by the table. Active egg laying begins on an average of 11 days after the emergence of the first moth and the mid-point of active egg laying is not reached for 25 days. The duration of the deposition of the first-brood averages 47 days, with a very active period of approximately 30 days.

***Just as this paper was completed the moth emergence for 1934 started on April 21, thereby establishing a new early record for moth emergence. This is 21 days earlier than any previous record, thus making a variation of 40 days from the earliest date of moth emergence to the latest date for the beginning of the spring-brood emergence, instead of 19 as stated above.

Table 4.—Duration of codling-moth activities for first and second-brood moths. Paonia, Colorado

Year	Date of first moth	Number of days from first moth to— First egg	Emergence Activity	Emergence Mid-point of activity	Deposition Activity	Deposition Mid-point of activity	Number of days of— Moth emergence	Active moth emergence	Egg de-position	Active egg deposition
					First brood					
1918	May 21	14	11	19	16	31	53	28	51	31
1919	May 15	4	5	20	10	26	48	28	77	38
1920	May 26	6	7	16	11	24	46	22	45	29
1921	May 13	11	8	24	15	31	53	32	48	36
1922	May 23	7	4	13	8	18	26	11	29	22
1923	May 24	4	2	11	6	16	23	11	34	25
1924	May 16	8	4	12	16	30	36	23	46	28
	Average days	**7.7**	**5.6**	**16.4**	**11.7**	**25.1**	**40.7**	**22.1**	**47.1**	**29.8**
					Second brood					
1917	July 19	3	3	25	6	27	63	43	67	47
1918	July 7	7	6	31	7	31	75	50	66	51
1919	July 1	1	2	31	4	41	81	47	87	74
1920	July 16	1	6	26	4	27	66	40	78	47
1921	July 13	2	2	17	4	28	48	30	51	46
1922	July 14	3	2	14	5	27	35	32	51	44
1923	July 20	4	4	25	4	26	54	42	54	45
1924	July 15	3	4	14	3	21	48	21	61	37
	Average days	**3.0**	**3.6**	**22.8**	**4.6**	**27.2**	**58.8**	**38.1**	**64.3**	**48.8**


EGG DEPOSITION
SEASONS
1917-'18-'19-20
PAONIA-COLO.
1917
1918
1919
1920
MAY JUNE JULY AUGUST SEPT
25 30 4 9 14 19 24 29 4 9 14 19 24 29 3 8 13 18 23 28 2 7 12 17 22
4500 3000 1500 0
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6000 4500 3000 1500 0
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55° 50° 45° 40° 35°
60°

Oviposition.—The average number of eggs laid by female moths in captivity is somewhat less than in the orchard; however, it will serve as an index for the comparison of seasonal variations. From 6,764 female moths of the spring brood there were recorded 129,971 eggs, which is an average of 19 eggs per female. Over a period of 7 years the average per female varied from 6 eggs in 1923 to 24 in 1919. (Table 2.) The peak of egg laying occurs from the fifth to the seventh day of the life of the moth.

Incubation.—The yearly average incubation period of the first-brood eggs varied from 8.2 to 9.7 days. The minimum incubation period was 6 days.

First-Brood Larvae.—The earliest first-brood larvae hatch in 15 days following the appearance of the spring-brood moths. This means that the first cover spray should be completed in 14 days following the appearance of the first spring-brood moths. This allows time enough for the moth activity and egg incubation to proceed to the point of active larval hatching.

The average length of the larval stage in the fruit varies from 23 to 27 days with a minimum of 17 days. Mature larvae of the first brood often appear in the North Fork Valley the last week of June or the forepart of the first week of July, but most usually the first larvae are taken under the bands about July 4. Some early records have been made of first larvae under the bands by June 20. It has been the policy to recommend that June 20 be the zero hour for banding trees to catch the first-brood larvae.

First-Brood Pupae.—The period of time after the first-brood larvae leave the apple until the second-brood moths appear (which includes pre-pupal and pupal periods) has been termed "pupal period." The average length of the pupal period for the different years has ranged from 16 to 22 days with a minimum individual record of 12 days.

First-Brood Moths.—The earliest records of first-brood moths vary from July 1 to as late as July 20; in 6 of the 8 years of laboratory records the first moths appeared after July 12. The yearly average life of the first-brood moths varies from 9 to 16 days.

Emergence of the first-brood moths reaches the active period more rapidly than in the case of the spring brood. The active stage is reached in approximately 4 days from the appearance of the first moth. The duration of the emergence period averages almost 50 percent longer than with the spring brood, being nearly 60 days of continuous emergence.

Table 5.—Seasonal variations in the codling-moth activities in the laboratory, Paonia, Colorado.

	Time of occurrence Early and late	Average date	Number days variation	Number days to—	Variation	Average days
First Brood						
Full bloom (Jonathan)	May 3 to May 23	May 12	20	Calyx spray 9—15	6 days	11 days
Calyx spray	May 9 to May 29	May 22	20	First cover spray 14—33	19 days	22 days
First moth	May 11 to May 30	May 18	19	Peak of emergence 5—16	19 days	9 days
				First egg 6—14	8 days	8 days
				Peak of egg deposition 17—32	15 days	24 days
				First cover spray 19—26	7 days	22 days
Second Brood						
First moth	July 1 to July 20	July 13	19	Peak of emergence 9—26	17 days	13 days
				First egg 1—7	6 days	3 days
				Peak of egg deposition 19—53	34 days	28 days
				Third cover spray 7—25	18 days	17 days

Second-Brood Eggs.—The deposition of second-brood eggs progresses very rapidly, the active egg laying being reached in 5 days following emergence of the first moth. The active egg-laying period covers 48 days with a continuous oviposition of 64 days. This is responsible for the long-drawn-out appearance of small larvae which so often ruin the fruit during the latter part of August and into the month of September.

The average number of eggs laid per female, which is 48, is more than twice the average for the first brood. This average was obtained from a record of 6,595 female moths which deposited 317,588 eggs. The minimum average for any one season was 30 and the maximum 65 eggs per female. This is an important factor which contributes to the difficulty experienced in controlling the second-brood larvae and emphasizes the importance of control of the first brood.

Incubation.—Incubation of the second-brood eggs requires from 6 to 9 days, and is only slightly shorter than the time required for the first-brood eggs.

Establishment of Spray Dates

For the North Fork Valley and the Surface Creek Valley above Eckert, the standard spray schedule has called for the calyx spray and four cover sprays for the season. The four cover sprays have usually been equally divided, two for the first brood and two for the second brood of larvae. Such a schedule has for the most part been satisfactory except in case of seasons such as 1919, 1923, 1931, 1932 and 1933, when the second brood was scattered over an active period of from 65 to 70 days. In such instances it becomes necessary to use more than two cover sprays for protection from the second-brood larvae. This is particularly true of that area of Delta County known as the Austin-Cory District. Here we have a higher percentage of the first brood transforming and a longer occurrence of the second brood each season.

From 1917 to 1924 the spray dates were established upon laboratory records of moth emergence, while from 1925 to 1933 the activity of the moths taken from records of moth traps has formed the basis for spray dates. This method has been adopted because it is more flexible and can be more easily carried out at several points within the county. It has also proved to be highly efficient as an index to actual field activity of the moths. Table 3 contains the actual spraying dates as established from 1917 to 1933, inclusive, and also the date of the first moth flight of each brood along with the approximate peak of moth emergence. This table applies particularly to the Paonia District and is representative of the variations to be found in any portion of the county over a period of 17 years.

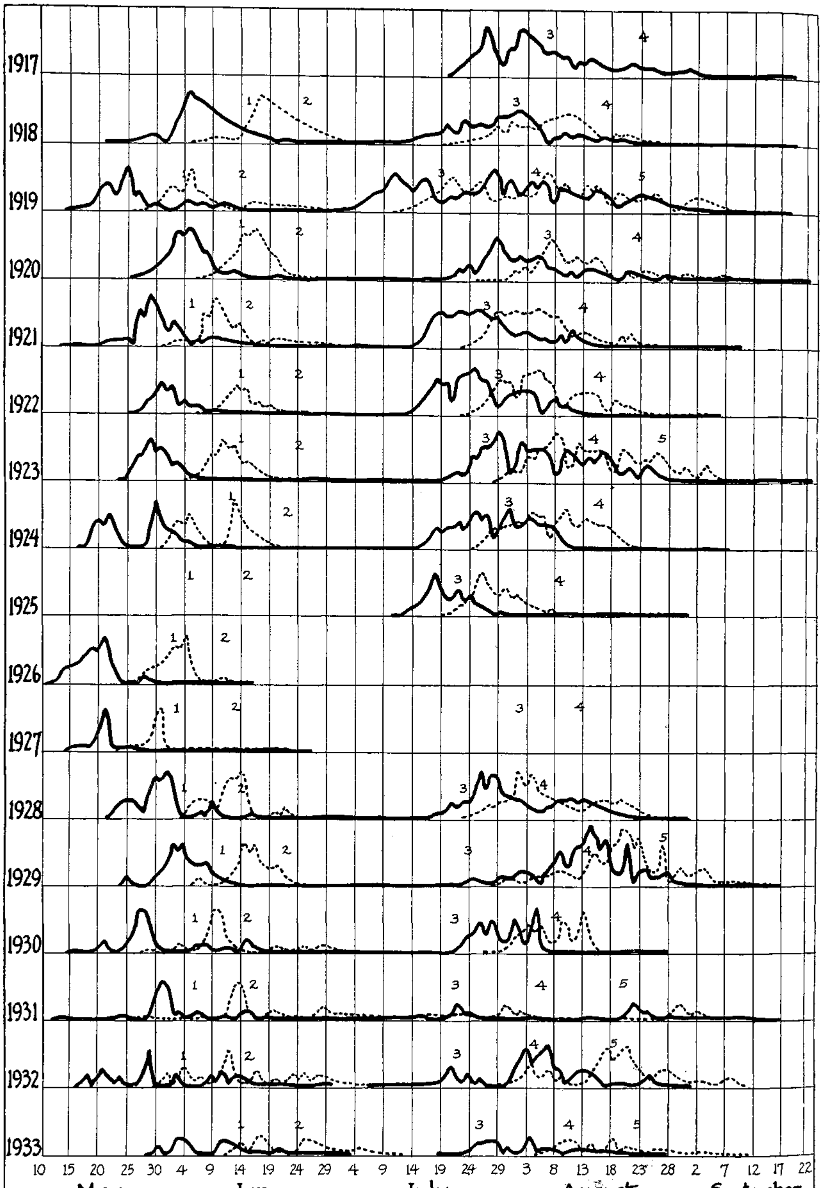

Fig. 2—Moth emergence and approximate codling-moth egg-hatching curves at Paonia, Colorado, 1917-1933, inclusive. Solid line—moth emergence; broken line—approximate egg hatching. Cover sprays marked 1, 2, 3, 4 and 5.

Laboratory records and trap records made in the field indicate that the dates of activities herein presented are very nearly identical with similar records taken at Montrose, Hotchkiss, Eckert and Redlands Mesa, and that orchards above Cedaredge are 1 or 2 days later than Paonia, while Olathe precedes Paonia by 1 or 2 days. The author is of the opinion that the difference between any of these points would not exceed 3 or 4 days at the most.

The difference in the time of occurrence of moth activity from one district to the other is not as large as the apparent variations in blooming dates. For the Paonia and Austin Districts the difference in blooming is not less than 10 days and often as much as 3 weeks, whereas the difference in moth activity averages 7 days with a maximum of 15 days. See Table 6.

Calyx Spray.—It is well to keep in mind that the purpose of the calyx spray is to place poison in the calyx cup before the calyx lobes have closed over the cup proper. This is an important factor in codling-moth control because the small larvae find within the calyx cup a convenient hiding place and point of attack that is ideal for an easy entrance into the fruit. Protection of the calyx from codling-moth entrance by the use of the calyx spray continues throughout the season and is not for immediate control at the time of application. The proper time for the application of the calyx spray is when the calyx lobes have raised to the point of forming a cup that will be most receptive of the spray. The time at which this occurs will vary from 7 to 15 days from the date of full bloom, with an average of 10 days. Most usually this will be when approximately 90 percent of the petals have fallen, providing they have not been blown off prematurely. The author believes this spray to be the most important of the season since data at hand have often shown 40 to 60 percent of the larvae entering at the calyx cup on unsprayed trees.

Certain varieties such as Jonathan bloom evenly and are uniformly receptive for the calyx spray, while in others such as Rome Beauty the bloom is uneven to the extent that they often require a second application in order to effectively fill all the calyx cups for efficient control.

Cover Sprays

Cover sprays are for the express purpose of covering the fruit with a protective material to act as a stomach poison for the larvae at the time they attempt to enter the fruit. They also serve as a coverage of the leaf surface upon which many of the larvae are killed before reaching the fruit. It is important to realize the value of complete coverage of the tree as a unit in applying cover sprays.

The timing of sprays is so planned as to give coverage dur-

Table 6.—Comparative occurrence of moth flight at Austin and Paonia, Colorado.

	Spring brood				First brood				
	First moth		Peak emergence		First moth		Peak emergence		Week of late heavy flight at Austin
Year	Austin	Paonia	Austin	Paonia	Austin	Paonia	Austin	Paonia	
1922					July 4	July 14	July 18	July 23-26	Aug. 16-23
1923	May 9	May 24	May 20	May 29	July 4	July 20	July 19	July 29	July 11, Aug. 25
1924	May 12	May 17	May 19	May 24-31	July 8	July 15	July 17	July 22-27	Aug. 16-23
1925					June 30	July 15	July 6	July 20	Aug. 15-22
1926	May 7	May 11	May 22	May 22					
1927	May 10	May 15	May 20	May 21	July 9	July 18	July 18	July 26	Aug. 13-20
1928	May 10		May 27			July 20		July 28	
1929		May 24		June 5	July 14	July 16	July 20	Aug. 9	Aug. 1-7

ing the hatching of the major portion of each brood. While it is impossible with only two cover sprays for each brood to cover the entire period completely, they are so arranged as to give maximum protection over the most active period. Additional cover sprays can be employed to lengthen the protective period. Theoretically, additional sprays should be applied toward the first-brood control, however, in actual practice, if only one additional cover spray is to be applied, it will afford greater protection if used on the second brood, which requires a longer period of protective coverage. This has been true throughout the experimental work in all cases except one.

First Cover Spray.—During 16 years of records at Paonia the dates for completion of the first cover spray have been equally distributed from June 2 to 8 or from June 12 to 16. In other words, it has been either the first week or the latter part of the second week. It is interesting to note that there have been no intermediate dates. The average lapse of time between the calyx and the first cover spray has been 22 days, with a minimum of 14 days.

Second Cover Spray.—The second cover spray has been applied from 10 to 12 days after the first cover spray, for two general reasons: First, a cover spray will maintain a protective coat for a period of approximately 10 days with the rate of growth of the fruit that occurs at this time, and second, the duration of the brood requires a protective covering for an approximate period of 4 weeks.

Third Cover Spray.—Time for application of the third cover spray depends upon the intervening weather. From 14 seasonal records the average time from the second to the third cover spray has been 39 days, with a minimum of 31 and a maximum of 54 days. The dates of the third cover spray show greater variation than any of the other sprays of the season. The earliest date being July 19 and the latest date August 7, while a majority fall within the last week of July.

Fourth Cover Spray.—The fourth cover spray has been scheduled from 14 to 16 days following the third cover spray, depending upon the codling-moth activity recorded during that period of time. The time between the last two cover sprays has been lengthened because of the slower rate of growth of the fruit and the longer period of time covered by the second brood of moths.

Seven Years of Spray Experiments

Seven years of spray experiments were conducted during the 10-year period from 1920 to 1930. This work was carried on in several different orchards and for the most part was not as closely correlated as it could have been had the work been carried on in a single orchard. Experimental work for the seasons of 1931, 1932 and 1933 was carried on in the same orchard, therefore the results will be considered as a unit in this report.

There are some general points of interest from the spray work of 1920 to 1929 that will warrant definite statements concerning certain spray practices. These can best be pointed out under general headings as follows:

1.—The standard spray schedule as termed in this report consists of the calyx spray and four cover sprays, two for the control of each brood of worms.

2.—Three sprays (calyx and two cover sprays): When applied to the first brood alone, failed to control. When applied as one cover spray for each brood, failed to control whether double or single strength lead arsenate was used. The addition of a spreader did not increase the control.

3.—Four sprays (calyx and three cover sprays): When applied as one cover spray for the first brood and two for the second brood, gave control almost equal to the standard schedule. The reverse arrangement of these cover sprays, which should theoretically give the greater protection, has failed in most cases. This might be expected in that the duration of the first brood, being normally about 3 weeks, can be more nearly covered by one spray than in the case of the second brood which is often spread over a 4-to-6-weeks period.

4.—Five sprays: The five spray schedule has been set up as the standard schedule because it allows two cover sprays to be applied for each brood. There are some seasons in which an extra cover spray might be used to advantage near the end of the second brood.

5.—Spreaders: The use of spreaders has given a more uniform coverage, but it has not resulted in any material increase in the effectiveness of lead arsenate sprays.

6.—Amounts of lead arsenate: The use of increased amounts of lead arsenate to as much as double the normal dosage has not given enough increased control to warrant the added cost. Lead arsenate used at one-half strength failed to control. The standard amount is 2 to 2 and one-half pounds per 100 gallons of spray solution.

7.—Substitutes for lead arsenate: (For second brood only). The substitution of black leaf 40 in the third and fourth cover sprays did not equal the standard spray schedule. The results of 1927 do not prove that this substitute gave any protection since the omission of cover sprays entirely for the second brood gave equal control. This would seem to indicate that this was a season of practically no moth activity in the second brood. This experience of 1927 emphasizes the importance of always having a check or standard plot for comparison of any spray material or practice. Four cover sprays of oil (lead arsenate in the calyx and last cover spray only) failed to control. Nicona, an oil and nicotine mixture, improved control. Derrisol as a substitute for lead arsenate in the second-brood sprays failed to control.

8.—Combination sprays: The addition of oil to the lead arsenate cover sprays resulted in improvement of the control as evidenced by the decrease of the total number of injured fruit, both wormy and stung-only.

Proportions of Materials Used in 100 Gallons of Spray Solution, (1920, 1922, 1923, 1926, 1927, 1928 and 1929).—

Standard lead arsenate	2 pounds
Dust application, 78 percent lead arsenate, 2 percent nicotine sulphate, 20 percent hydrated lime	
"Kayso" as spreader	1 pound
Lead arsenate (double strength)	4 pounds
Black leaf 40	1 pint
Derrisol	1 pint
Volck oil	1 gallon
Lead arsenate, 1½ strength	3 pounds
Nicona	1 gallon
Medol	1 gallon

Spray Experiments of 1931, 1932 and 1933

The experiments as reported were largely in search of a substitute for lead arsenate. It was hoped that a spray schedule or substitute material could be found that would give control and at the same time permit the fruit to meet the federal tolerance on spray residue, without the cost of washing. It was soon discovered that a suitable substitute for lead arsenate was difficult to find and further that the application of lead arsenate in only the first-brood cover sprays left enough residue to be over the world tolerance of .01 grains of arsenic and .019 grains of lead per pound of fruit.

The experiments for 1931, 1932 and 1933 were carried on in the same orchard and under conditions for proper repetition of tests and studies. This has been most valuable because of the detailed knowledge of the codling-moth population and fruit production. Practically all of the spray plots were run in duplicate and of such a size that the methods of application and operation were kept as nearly to a commercial basis as possible. In every case each plot was made up of at least 3 rows. There were from 15 to 35 trees per plot arranged in such a way that nearly all counts could be made upon trees of the center row. The 2 outside rows therefore represent buffer rows which protected the actual count trees from spray drift. The results presented in the data are based upon counts made of all the fruit upon 4 trees from each plot. The orchard was so divided that each experiment was run in duplicate, but with different varieties. For 1931 and 1932 there was a standard plot adjacent to each test plot. The data presented for 1933 are considered the most valuable.

Experimental Spray Experience for the Season of 1931—Harvest Plus Windfall Count.—

Rome Beauty	Delicious
Comparisons made against standard schedule	
Standard (65 percent injured) (15 percent wormy, 50 percent stung-only)	Standard (39 percent injured) (4 percent wormy; 35 percent stung-only)

Combination spray of oil and lead arsenate in first cover spray.

16 percent less injured fruit.	6 percent less injured fruit.
1 percent less wormy fruit.	2 percent less wormy fruit.
15 percent less fruit stung-only.	4 percent less fruit stung-only.

Combination spray of oil and lead arsenate in first and third cover sprays.

17 percent less injured fruit.	8 percent less injured fruit.
7 percent more wormy fruit.	4 percent less wormy fruit.
26 percent less fruit stung-only.	12 percent less fruit stung-only.

Three sprays of lead arsenate. Calyx and two cover sprays for the first brood. Cryolite in third and fourth cover sprays.

13 percent less injured fruit.	No difference in total injured fruit.
1 percent less wormy fruit.	2 percent more wormy fruit.
12 percent less fruit stung-only.	2 percent less fruit stung-only.

Three sprays of lead arsenate. Calyx and two cover sprays for first brood. Barium fluosilicate (dutox) for the third and fourth cover sprays.

3 percent less injured fruit.	2 percent more injured fruit.
19 percent more wormy fruit.	7 percent more wormy fruit.
22 percent less fruit stung-only.	5 percent less fruit stung-only.

Three sprays of lead arsenate. Calyx and two cover sprays for the first brood. Oil and nicotine (black leaf 40) for the third and fourth cover sprays.

5 percent less injured fruit.	20 percent less injured fruit.
34 percent more wormy fruit.	5 percent more wormy fruit.
39 percent less fruit stung-only.	25 percent less fruit stung-only.

Five sprays of lead arsenate plus fish oil as a spreader in the first and second cover sprays.

5 percent less injured fruit.	8 percent more injured fruit.
34 percent more wormy fruit.	12 percent more wormy fruit.
39 percent less fruit stung-only.	4 percent less fruit stung-only.

Summary (1931).—1.—The use of summer oil in combination with lead arsenate in the first cover spray improved control for both varieties by reducing the total fruit injured.

2.—The use of oil in the first and third cover sprays in combination with lead arsenate did not improve control. This failure to improve control may be due to a light crop in the Rome Beauty plot and also to the heavy moth population in the vicinity of the plot.

3.—The use of cryolite in the third and fourth cover sprays for control of the second-brood larvae was equal to the lead arsenate in all respects and resulted in 13 percent less injured fruit composed of 12 percent less fruit stung-only and 1 percent less wormy fruit in the Rome Beauty plot.

4.—The use of barium fluosilicate (dutox) in the third and fourth cover sprays for control of the second-brood larvae failed to protect the crop, resulting in 34 percent more wormy fruit for Rome Beauty and 5 percent increase in wormy fruit for Delicious.

5.—The use of oil and nicotine (black leaf 40) for the third and fourth cover sprays for control of the second-brood larvae failed to protect the crop, resulting in 19 percent more wormy fruit for Rome Beauty and 7 percent increase in wormy fruit for Delicious.

6.—Five sprays of lead arsenate with fish oil as a spreader and sticker in the first and second cover sprays resulted in what appears to be a failure to control. It is the opinion of the author that comparison cannot be made between this plot and the standard check plot, since they did not seem to have equal moth populations. This brings out the importance of having check plots distributed throughout the orchard so as to permit a more direct comparison.

7.—It will be noted that the ratio of stung fruit to wormy fruit is directly in proportion to control obtained; that is, efficient control is evident by the increase in number of fruit stung-only, whereas in the failure of control the number of wormy fruit increase indirectly as the fruit stung-only decrease. This may not hold the same relation in cases where an ovicide is used.

Experimental Spray Experience for the Season of 1932—Harvest Plus Windfall Count.—

Rome Beauty	Delicious
Comparisons made against standard schedule.	
Standard (47 percent injured) (18 percent wormy; 29 percent stung-only)	Standard (12 percent injured) (1 percent wormy; 11 percent stung-only)
Standard spray of lead arsenate applied at 500 pounds pressure from the ground and top of the tank.	
18 percent less injured fruit. 12 percent less wormy fruit. 6 percent less fruit stung-only.	Control same as standard in all respects.
Lead arsenate in calyx spray. Four cover sprays of cryolite.	
8 percent less injured fruit. 6 percent more wormy fruit. 11 percent less fruit stung-only.	12 percent more injured fruit. 7 percent more wormy fruit. 5 percent more fruit stung-only.
Three sprays of lead arsenate. Calyx and two cover sprays for the first brood. Cryolite for the third and fourth cover sprays for second brood.	
5 percent more injured fruit. 11 percent more wormy fruit. 5 percent less fruit stung-only.	9 percent more injured fruit. 5 percent more wormy fruit. 4 percent more fruit stung-only.
Standard spray of lead arsenate in combination with summer oil in the second and third cover spray.	
21 percent less injured fruit. 8 percent less wormy fruit. 13 percent less fruit stung-only.	Total injured fruit the same. Approximately 2 percent less fruit stung-only.
Standard spray of lead arsenate using 300 pounds pressure.	
7 percent less injured fruit. 2 percent less wormy fruit. 5 percent less fruit stung-only.	Control approximately the same as standard in all respects.
Standard spray of lead arsenate plus fish oil as a sticker in the first and second cover sprays.	
6 percent less injured fruit. 3 percent less wormy fruit. 3 percent less fruit stung-only.	No Delicious plot.

Three sprays of lead arsenate. Calyx and two cover sprays for the first brood. Cryolite (kalo) in the third and fourth cover sprays.

No Rome Beauty plot.	4 percent more injured fruit. 3 percent more wormy fruit. 1 percent more fruit stung-only.

Summary (1932).—1.—As an improvement in spray application the use of an operator from the top of the tank in combination with an operator from the ground did not improve the control for Delicious but in the case of the Rome Beauty there was an outstanding decrease in the total injured fruit.

2.—The substitution of cryolite for lead arsenate in the four cover sprays gave control a little below the standard.

3.—The use of cryolite in the third and fourth cover sprays for control of the second-brood larvae gave control below the standard.

4.—The use of summer oil in the second and third cover sprays in combination with lead arsenate improved the control.

5.—Three hundred pounds of pressure in comparison with 500 pounds of pressure with applications from the ground gave equal control. This demonstrates that thoroughness depends upon the individual.

6.—The use of fish oil as a sticker and spreader in the first and second cover sprays improved the control to a slight extent.

7.—The use of sodium-fluoaluminate (kalo) for the third and fourth cover sprays gave control approximately equal to the standard.

Experimental Spray Experience for the Season of 1933—Harvest Plus Windfall Count.—

Rome Beauty	**Delicious**

Comparisons made against a standard schedule in each plot.*

Standard spray schedule plus lime in all of the cover sprays. (Lime caseinate spreader formed.)

Rome Beauty	Delicious
20 percent less injured fruit.	13 percent more injured fruit.
11 percent less wormy fruit.	10 percent more wormy fruit.
9 percent less fruit stung-only.	3 percent more fruit stung-only.

*The standard schedule in 1933 consisted of arsenate of lead in the calyx and four cover sprays with calcium caseinate spreader in the last.

Standard spray schedule of special lead arsenate.

13 percent more injured fruit.	6 percent less injured fruit.
Wormy fruit same as standard.	6 percent less wormy fruit.
13 percent more fruit stung-only.	Fruit stung-only same as standard.

Standard spray schedule (no lime throughout the season).

4 percent less injured fruit.	3 percent less injured fruit.
2 percent more wormy fruit.	3 percent less wormy fruit.
6 percent less fruit stung-only.	Fruit stung-only same as standard.

Four cover sprays of zinc arsenite.

Injured fruit same as standard.	7 percent more injured fruit.
9 percent more wormy fruit.	14 percent more wormy fruit.
9 percent less fruit stung-only.	7 percent less fruit stung-only.

Four cover sprays of special zinc arsenite.

1 percent less injured fruit.	10 percent more injured fruit.
4 percent more wormy fruit.	21 percent more wormy fruit.
6 percent less fruit stung-only.	11 percent less fruit stung-only.

Four cover sprays of zinc arsenate.

4 percent more injured fruit.	27 percent more injured fruit.
16 percent more wormy fruit.	26 percent more wormy fruit.
12 percent less fruit stung-only.	1 percent more fruit stung-only.

Four cover sprays of calcium arsenate.

13 percent less injured fruit.	27 percent more injured fruit.
3 percent less wormy fruit.	36 percent more wormy fruit.
10 percent less fruit stung-only.	9 percent less fruit stung-only.

Four cover sprays of cryolite (kalo).

	13 percent less injured fruit.
No plot for Rome Beauty.	9 percent less wormy fruit.
	4 percent less fruit stung-only.

Six cover sprays of lead arsenate.

17 percent less injured fruit.	6 percent less injured fruit.
20 percent less wormy fruit.	9 percent less wormy fruit.
3 percent more fruit stung-only.	10 percent more fruit stung-only.

Five cover sprays of lead arsenate. Three for the first brood and two for the second brood.

27 percent less injured fruit.	1 percent more injured fruit.
18 percent less wormy fruit.	9 percent less wormy fruit.
9 percent less fruit stung-only.	10 percent more fruit stung-only.

Five cover sprays of lead arsenate. Two for the first brood and three for the second brood.

16 percent less injured fruit.	Injured fruit same as standard.
12 percent less wormy fruit.	3 percent less wormy fruit.
4 percent less fruit stung-only.	3 percent more fruit stung-only.

Summary (1933).—1.—The addition of lime to the lead arsenate spray, which reacted with the casein in the spray to form a lime-caseinate spreader improved the control for the Rome Beauty, but gave less control for the Delicious.

2.—The special lead arsenate gave equal control for the Rome Beauty and showed some improved control for the Delicious.

3.—The standard spray schedule of lead arsenate gave like control in the case of both varieties.

4.—The substitution of four cover sprays of zinc arsenite for lead arsenate gave poor control.

5.—The substitution of four cover sprays of special zinc arsenite gave control equal to the standard for the Rome Beauty but failed in the case of the Delicious.

6.—Four cover sprays of zinc arsenate substituted for lead arsenate gave very disappointing results.

7.—Four cover sprays of calcium arsenate gave control equal to the standard for the Rome Beauty but failed very materially to protect the Delicious.

8.—Four cover sprays of kalo (cryolite) gave control equal to the standard on Delicious.

9.—Six cover sprays of lead arsenate in place of the usual four cover sprays gave very marked improvement of control.

10.—Five cover sprays of lead arsenate, using three for the first brood and two for the second brood improved the control.

11.—Five cover sprays of lead arsenate, using two for the first brood and three for the second brood improved the control.

12.—In the five cover-spray schedule, the application of three for the first brood and two for the second brood gave better control than in the reverse schedule of two for the first brood and three for the second brood.

13.—The use of the probable error (P. E.) factor in interpreting the data for 1932 and 1933 is valuable as an index of the significance of the difference in the control presented in the data.

Summary of Spray Experience for 1931, 1932 and 1933

Three years of studies and spray experience in the same orchard have brought out the following points in relation to codling-moth control:

1.—That the codling-moth population within an orchard varies from season to season.

2.—That the codling-moth population is not evenly distributed within a given orchard.

3.—That reliable comparison of any spray schedule or material must be made against the competitive material or schedule within the same or an adjoining plot.

4.—That the characteristic differences of varieties such as type of foliage, density of growth, skin texture and pubesence are factors which enter into codling-moth control. For instance, it is well known and often demonstrated that Wine Saps are more easily protected than Delicious and they in turn are more easily protected than the Rome Beauty. The fact that the Rome Beauty is produced upon willowy fruit spurs is responsible for a greater proportion of the spray being rubbed off by the leaves brushing against the fruit.

5.—That the spray-residue analyses show the Delicious to retain a greater deposit than the Rome Beauty. This may be due to some character of the skin surface and to the fruit being more stably attached so that leaf rubbing does not occur.

6.—That the addition of summer oil in combination with lead arsenate improves the control when used in the standard spray schedule.

7.—That the combination of oil and lead gives greatest efficiency when used in control of the first brood.

8.—That the use of spreader with lead arsenate has not materially improved the control.

9.—That the use of cryolite (sodium-fluoaluminate) gives control approximately equal to the standard schedule.

10.—That the following substitutes for lead arsenate in the cover sprays have failed to give uniformly satisfactory control; black leaf 40 and oil, oil alone, barium fluosilicate, zinc arsenite, zinc arsenate and calcium arsenate.

11.—That the use of pressure above 300 pounds is desirable and worth while when efficiently used, however, it is not essential to good spray work providing the size of opening of the nozzle is adapted to the pressure at hand. Successful codling-moth control depends to a large extent upon the operator.

12.—That an operator spraying from the top of the tank or tower will improve the control on the larger trees. This seems to be particularly true for Rome Beauty wherein the willowy type of growth prevents thorough application of the spray from the ground.

Proportions of Materials Used in 100 Gallons of Spray Solution, 1931, 1932 and 1933.—

Arsenate of lead	2½ lbs. plus ½ lb. hydrated lime.
Mineral or volck oil	1 gallon.
Cryolite	4 lbs. plus 1 pint of fish oil.
Cryolite (kalo)	4 lbs. plus 1 pint of fish oil.
Fish oil	1 pint.
Black leaf 40	1 pint.
Special lead arsenate	2 lbs. plus ½ lb. hydrated lime.
Zinc arsenite	2½ lbs. plus 1 lb. hydrated lime.
Zinc arsenite special	2½ lbs. plus ½ lb. hydrated lime.
Zinc arsenate	2½ lbs. plus ½ lb. hydrated lime.
Calcium arsenate	2½ lbs. plus 2½ lbs. hydrated lime.
Barium fluosilicate (dutox)	3 lbs. plus 1 pint of fish oil.

Arsenical Residues at Harvest.—There is considerable variation in the amount of residue on the fruit at harvest time depending upon the weathering which has taken place during the season. The arsenical residue from the standard spray schedule, which consists of the calyx spray and four cover sprays, ranges from .024 to .157 grains per pound of fruit at harvest. The use of fish oils and mineral oils increased the residue in most cases. The substitution of other materials for lead arsenate in the third and fourth cover sprays did not hold the arsenical residue at harvest time below the world tolerance of .01.

It is interesting to note that in 1932 the residue on Delicious was consistently higher than on Rome Beauty. While this relationship may not continue through every season, it may be a factor contributing to the better control of codling moth on Delicious in comparison with Rome Beauty.

With the present washing equipment in use by the packing houses and associations, the problem of meeting the present tolerance on lead as well as arsenic, is well in hand. Of 386 samples submitted to the growers' laboratory in 1933, 18 carried .019 grains and 58 carried .014 grains of lead per pound. Only 3 percent of the total samples were above the 1933 lead tolerance of .02.

Data

The data presented in this test were gathered by scoring all of the blemishes upon the harvest and windfall fruit.

The windfall count includes the dropped fruit beginning the first of August through to completion of the harvest. While this does not include the June drop, and in some cases the fruits removed in thinning, it has accounted for the major portion of the windfall fruit of the season.

The method used in scoring is one adopted for some time by this department. All of the fruit for a given sample is first counted then each is scored for the number of codling-moth blemishes. This scoring records all open worm holes as worms, and all healed codling-moth injuries as stings. From it the following facts can be tabulated: Total fruit free from all injuries; injured fruit; wormy fruit; fruit with stings-only; total number of worms recorded as calyx worms, stem worms, side worms, total blemishes, etc.

Natural Control.—The native egg parasite *Trichogramma minutum Riley*, is general throughout the district. It can be found most numerous during the latter part of the second brood. Natural parasitism by this parasite is often as high as 50 to 60 percent during the latter part of September.

Artificial rearing and introduction of this parasite was undertaken during the seasons of 1930, 1931 and 1932. Intermittent and continuous liberations made in several orchards gave varying amounts of parasitism. In several instances the native parasitism was equal to or greater than in those blocks where heavy liberations were made from the laboratory.

A small liberation of some 60 individuals of *Ascogaster carpocapsae* was made in the Merle Miller orchard in 1928, however, laboratory rearing has failed to indicate that the species became established.

Supplementary Control Measures

Orchard Sanitation.—Successful control of the codling moth depends not alone upon spraying but upon an organized program of intelligent spray schedules coordinated with supplementary measures which tend toward better orchard sanitation. The moth population within an orchard determines the ease or difficulty in securing a successful control. Any operation that will help reduce the population should be considered. Orchard sanitation should be a major part of the orchard program, or in other words, serve as a foundation upon which to build a successful control program. This means the destruction of all hiding places that may occur in picking boxes, packing houses, underneath the bark on unscraped trees, in the crevices and cracks of neglected tree crotches, in the ground at the base of the tree, and in any debris of the orchard.

Tree Banding.—The use of tree bands is based upon the habit of the mature larvae to leave the fruit and seek shelter for the purpose of spinning cocoons in which to transform to moths. Since the larvae may stop at the first hiding place, it is essential that all rough bark be removed and the crotches cleaned of all debris to obtain the greatest value from the bands. Burlap bands have been used for a long time, but they are objectionable in that they require systematic attention at least every 10 days. The medicated band recently developed by the United States Bureau of Entomology is by far the greatest step made in codling-moth control during the last decade. While these bands have been in the process of development and trial, they have shown very encouraging results.

The preparation of the medicated band is a somewhat complicated process which requires certain equipment, specific materials, and due consideration of details, to obtain a good product. For the most part these bands have been made by fruit houses and cooperative concerns that are interested in furnishing this supplementary control measure to the grower at the lowest cost. Because of the importance of detail and the need for proper equipment, it is suggested that this practice be continued and improved for the good of the industry. Specific directions for the making of the bands can be obtained from the United States Bureau of Entomology or from the Colorado Experiment Station or office of State Entomologist at Fort Collins.

The greatest value from the use of bands cannot be obtained unless the trees are properly prepared by removing all rough bark and the cleaning of debris from the crotches. On some trees this is not a difficult job, while in the case of older trees and ones that have a tendency to produce bark extensively, it becomes quite a task. The value of tree scraping is very evident from a record made at Austin, Colorado, by Dodge and Downey* of three unsprayed trees. Two bands on scraped trees trapped 987 and 690 larvae respectively, from June 23 to August 6, whereas the band on an unscraped tree trapped only 212 larvae during the same period of time. In this case the band on the properly prepared trees trapped from three to nearly five times as many larvae as the band on the unscraped tree.

An interesting record of the number of larvae taken under bands in a commercial orchard for the years 1917, 1918, 1919,

*Fifteenth Annual Report, State Entomologist, Colorado, 1924.

1920, 1921 and 1922 was furnished the author by Vin Mathews of Paonia, Colorado. A summary of this record is as follows:

1917	245 trees	7,490 larvae
1918	475 trees	9,611 larvae
1919	480 trees	28,321 larvae
1920	480 trees	6,508 larvae
1921	480 trees	3,082 larvae
1922	480 trees	6,583 larvae
	Total	61,595 larvae

This is an average of 139 larvae per tree per season. This population per tree, which was removed by the banding process, has a potential progeny of 1,400 larvae to be controlled by the first-brood sprays. If these sprays were 75 percent efficient, the first-brood moths would number 350, half of which would be females capable of laying 8,400 eggs, which would represent the number of larvae to be controlled by the second-brood sprays. Therefore it is entirely probable that an efficient banding program is just as valuable as all the sprays of a season.

Pruning and Thinning.—The proper pruning of an apple tree so as to give an opportunity to apply the spray more thoroughly is an important factor for successful control. This should be so done that there are spray openings at three or four positions whereby all fruit may be sprayed from several angles. Trees with too many branches preclude successful control because the spray cannot be forced through to cover the fruit.

Thinning of the fruit at the proper time should aid control for two reasons: First, the breaking of clusters and the separation of fruits that touch will do away with favorable points where larvae are most apt to gain entrance; second, the wormy fruit can be picked and removed from the orchard as a part of the sanitation program.

Codling-Moth Traps

The trapping of the codling moth began at this station in 1922,* following the report that a certain grower in Mesa County was successfully trapping codling moths in jars of vinegar placed within the tree. Table 7 presents some of the trapping records at Paonia from 1922 to 1931.

The first trapping data were gathered during the second brood in 1922 wherein it was found that during the period from July 22 to September 25, a 10 percent solution of vinegar and

*Fifteenth Annual Report, State Entomologist, Colorado, 1924.

Table 7.—Codling-Moth Trap Records Taken at Paonia, North Fork Valley of Colorado

Date	Material	Number traps	Total moths	Females	Males	Average per trap	Number days	Orchard
1922								
July 22	Vinegar 5 %	6	98			16.3	45	Wm. Starks
to	Vinegar 10 %	6	147			24.4	45	Wm. Starks
Sept. 5	*Hooch	2	145			72.5	45	Wm. Starks
May 30								
to	Vinegar 5 %	12	467			28.8	98	Wm. Starks
Sept. 6	Vinegar 10 %	12	630			52.5	98	Wm. Starks
1928								
May 14								
to	Hooch	27	3,527			130.2	119	Merle Miller
Sept. 1								
1929								
July 21	Vinegar 10 %	5	171	83	88	34.2	42	Merle Miller
to	Hooch	5	381	228	153	76.5	42	Merle Miller
Sept. 1	No. 1 Diamalt 1-4	5	961	612	349	192.2	42	Merle Miller
	Diamalt 1-7	5	476	295	181	95.2	42	Merle Miller
Aug. 13	Diamalt 1-9	5	810	511	299	162.0	42	Merle Miller
to	Diamalt 1-12	5	299	154	75	45.8	19	Merle Miller
Sept. 1	Diamalt 1-19	5	233	165	68	46.6	19	Merle Miller
	(Fruit jars used as container for traps)							
July 21	No. 2 Diamalt 1-4	5	1,013	649	364	202.6	42	Merle Miller
to	Diamalt 1-7	5	735	461	274	147.0	42	Merle Miller
Sept. 1	Diamalt 1-9	5	808	548	260	161.6	42	Merle Miller
Aug. 13	Diamalt 1-12	5	240	160	80	48.0	19	Merle Miller
to	Diamalt 1-19	5	536	352	184	107.5	19	Merle Miller
Sept. 1	(Fruit jars used as container for traps)							
July 21	Vinegar 10 %	5	175	397	78	135.0	42	Merle Miller
to	Hooch	5	560	312	248	112.5	42	Merle Miller
Sept. 1	No. 1 Diamalt 1-4	5	1,267	802	465	203.4	42	Merle Miller
	Diamalt 1-7	5	610	383	227	122.0	42	Merle Miller
Aug. 13	Diamalt 1-9	5	939	590	349	187.0	42	Merle Miller
to	Diamalt 1-12	5	492	313	178	98.4	19	Merle Miller
Sept. 1	Diamalt 1-19	5	391	238	153	78.2	19	Merle Miller
July 21	No. 2 Diamalt 1-4	5	1,463	915	548	292.6	42	Merle Miller
to	Diamalt 1-7	5	864	550	314	172.2	42	Merle Miller
Sept. 1	Diamalt 1-9	5	1,647	1,001	616	329.4	42	Merle Miller
Aug. 13	Diamalt 1-12	5	834	492	342	166.8	19	Merle Miller
to	Diamalt 1-19	5	726	435	291	125.2	19	Merle Miller
Sept. 1	(Granite pans used as container for traps)							
Total				**10,326**	**6,205**			
			16,531 moths recorded					
1930								
May 15								
to	Diamalt 1-19	49	3,014	1,854	1,160	61.5	90	Art Roberts
Aug. 13								
1931								
May 12								
to	Diamalt 1-19	22	2,645	1,430	1,215	120.2	117	E. Allen
Sept. 6								

*"Hooch" was fermented apple juice.

water caught an average of 24 moths per trap. During the same time a fermented apple-juice solution caught 72 moths per trap, or, in other words, it was three times as efficient as the vinegar solution. This brief experiment was followed in 1923 and 1924 by more extensive trapping records carried on at Grand Junction* by W. P. Yetter, in which he tested the comparative value of several aromatic chemicals. A number of these showed some promise but none were as attractive as the fermented apple juice.

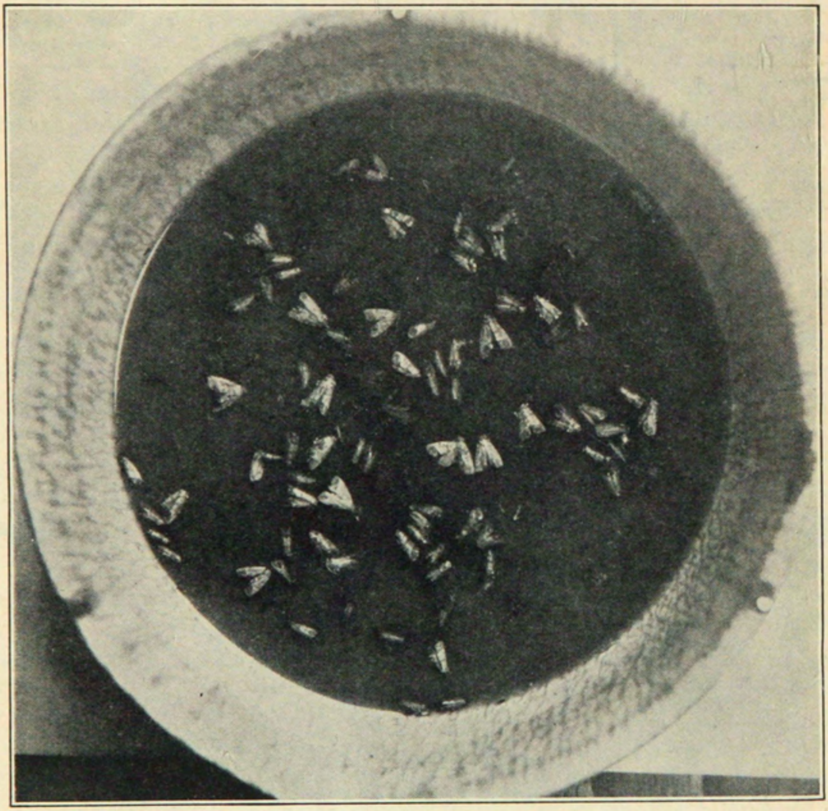

Fig. 3.—A "bait-pan" catch of approximately 80 moths in one night.

In 1929 an extensive experiment was carried on using Fleishman's diamalt as a basis for attrahent. The malt was used in the proportions of 1 to 4, 7, 9, 12 and 19 parts of water, and compared with the 10 percent vinegar solution and the apple ferment, designated as "hooch." The "hooch" proved to be from three to five times as attractive as the 10 percent vinegar solu-

*Fifteenth Annual Report, State Entomologist, Colorado, 1924.

tion. In the No. 1 diamalt series the proportions of 1 to 4 and 1 to 7 were equally attractive, trapping six times as many moths as the vinegar solution and two times as many as the "hooch." In the No. 2 diamalt series the proportions of 1 to 4, 1 to 9, and 1 to 19 were equally efficient and trapped seven times as many as the vinegar solution and two and one-half times as many as the "hooch." While these results are not consistent in the relative attractiveness of the several different dilutions of diamalt, it would seem that the dilutions of 1 to 9 or 1 to 19 could be depended upon for suitable results.

Comparison of pans and jars as containers for the attrahent places the pan above the jar by an increase in catch of nearly 50 percent. However, the pans are not without fault in that the material is easily lost through spilling and a high rate of evaporation. In this experiment 24 traps over a period of approximately 6 weeks and at the time of the second-brood flight, caught 16,631 moths of which 62 percent were females. During the past three seasons several of the malt syrups and molasses syrups have proved equally effective for trap use.

Codling-moth traps should be placed in the upper third of the tree to obtain the greatest efficiency. Data taken in 1922* showed that 85 percent of the total moths were from the traps placed in the upper third of the tree. Similar records made at Grand Junction have consistently given a like proportion in favor of the traps placed well up in the tree.

In 1930 an extensive experiment in the use of "diamalt" in the traps as a supplementary control measure failed to show definite improvement in control in the orchard of A. L. Roberts. A plot of 119 trees with traps in every tree gave a harvest count of 30 percent injured fruit made up of 7 percent wormy and 23 percent stung-only. A similar block of 220 trees with traps in every other tree gave a harvest count of 27 percent injured fruit consisting of 6 percent wormy and 21 percent stung-only. An untrapped block of 153 trees gave a harvest count of 27 percent injured, represented by 9 percent wormy and 18 percent stung-only. This would indicate that this particular test did not pay for the time and materials.

Test of Electrocutor Traps.—Through the cooperation of A. L. Roberts a test in the use of electrocutor traps was made during the season of 1930. In this test the electrocutor traps were mounted from poles to a position just above the top of the trees. A regular "hooch" trap containing "diamalt" as an attrahent was placed in the upper portion of a nearby tree to

*Fifteenth Annual Report, State Entomologist, Colorado, 1924.

serve as a check. A triangular cheese-cloth funnel was attached to a frame and suspended directly beneath the electrocutor trap in such a manner that it caught the moths killed by the trap. (See Fig. 4.) This cheese-cloth funnel was weighted at the bottom to make it swing directly beneath the trap at all times.

Two electrocutor traps, each with a jar of "diamalt" as an attrahent caught an average of 28 moths per trap for the season. Two electrocutor traps with "diamalt" and a 75-watt elec-

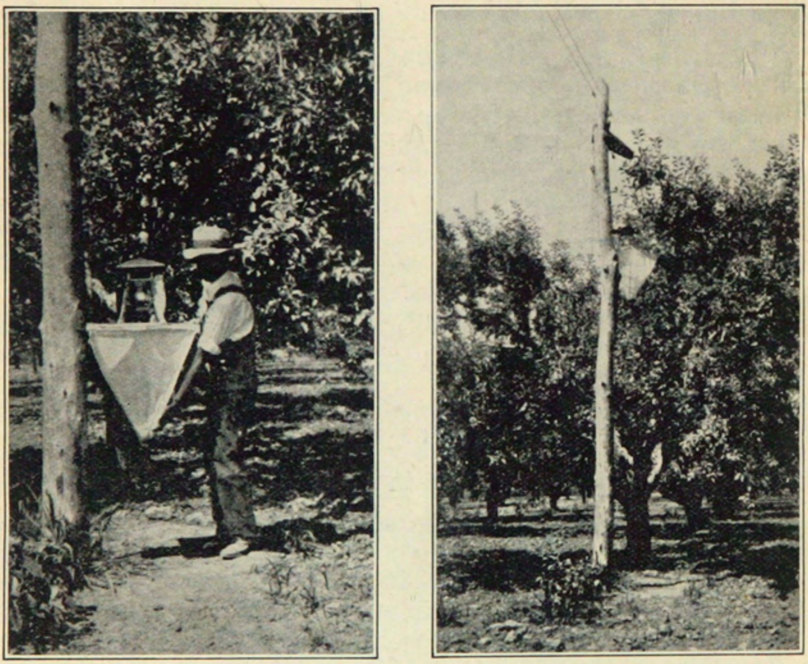

Fig. 4.—Electrocutor style of trap and cheese-cloth funnel as used in an experimental test in A. L. Roberts' orchard.

tric lamp caught an average of 95 moths for the season. One electrocutor trap with light but no "diamalt" caught 90 moths for the season. Three regular "hooch traps" caught an average of 73 moths per trap for the season. The five electrocutor traps caught an average of 68 moths per trap. This does not indicate any particular success with the electrocutor type of trap and it is interesting to note that very few moths were caught in this type of trap during the first brood. The initial cost and the cost of operation make electrocutor traps impracticable.

Time of Moth Flight.—An experiment to determine the time of flight of the moth during the 24-hour period was carried on in

1930. Hourly observations were made of 12 regular fruit-jar traps and 5 of the electrocutor traps from 4 p. m. July 24, to 12 p. m. July 25, a period of 32 hours. This represents 2 days' flight of the moth and indicates a very definite period of flight occurring from 7 to 8 p. m. On July 24, 70 percent of the moths were caught in this 1-hour period and on July 25, 94 percent. A few scattering moths were caught in the early afternoon and three in the early morning hours.

It is interesting to note that the peak of catch for the electrocutor traps was made from 8 to 9 p. m., 1 full hour later than in the regular traps; and that a considerable portion of the catch was scattered along from 8 to 12 p. m. Orchard temperature from 7 to 8 of each evening was 69 degrees F. at 7 o'clock and dropped to 66 degrees at 8 p. m. At 9 o'clock the temperature had dropped to 64 degrees and from then on very few moths were trapped.

The Use of Moth Traps for Establishing Spray Dates.—The greatest value in the use of moth traps comes from their record as an index of the seasonal moth activity as a basis for establishing spray dates. By their use the entomologist is able to determine accurately the time at which moths become active and from this, advise the growers of proper spraying dates.

Data collected in this way were for a number of years compared with laboratory and orchard-emergence records and found to be very dependable. This comparison began in 1922, but since 1927 the moth-trap records have been the principal source of information for the establishment of spray dates. The method has been quite generally adopted in the various fruit sections of the country. The first record of the use of trap data for this purpose seems to be by List* and was a mention of these studies at Paonia.

Every grower should run enough traps (6 or more) to determine moth activity within his own orchard, and in cooperation with the entomologist of the district, time his spray dates.

Improvement of Spray Practice.—Successful and economic control of the codling moth requires equipment that will apply the material in the most efficient manner. While it is not possible nor wise for everyone to own the latest of spray equipment, it is important that the equipment at hand be used in the most efficient manner. Satisfactory control depends upon complete coverage of the fruit and leaves at the proper time. To obtain the most from a cover spray it should be completed in 3 or 4

*Journal of Economic Entomology, Vol. 19, Page 748, 1926.

days. At present our orchard districts do not have enough machine power to apply the sprays within the required time. However, we should make the most of this by using spray nozzle equipment that will fit the machine in question and insure a well-broken type of spray. For those who rely upon custom spraying, it is suggested that you have your own equipment of spray nozzles selected to meet your requirements.

There has been considerable increase in the use of the higher spray pressures that range from 300 to 500 pounds. While increased pressures are convenient, they are not essential providing the nozzle's capacity is cut down to meet the capacity of the sprayer. Too often there is a tendency to use a large opening with a pressure of less than 300 pounds, resulting in a coarse spray which fails to give good coverage and at the same time is wasteful of material.

It is not possible to set a rule or measure for the amount of material required per tree or box of fruit. The old adage of "spare the spray and spoil the fruit" can be well taken. A little over-spray is far better than not enough. In the experimental plots of 1931, 1932 and 1933, an average of approximately 11 gallons per tree per application was used. Some of the better growers in the district are using similar and even greater amounts with success. The amount of material required for complete coverage depends upon the age of the tree and the pruning practice. Some investigators have set up the standard that the age of the tree divided by two would closely represent the number of gallons required for coverage.

Often the statement is made that this increased amount for coverage is too expensive. A 20-year-old tree, capable of bearing 10 boxes per season and requiring 10 gallons per application, would require 50 gallons of spray solution for the season which would contain 1.25 pounds of lead arsenate. With lead arsenate selling at 15 cents a pound, the cost of spray materials per box for the season would be less than 2 cents. The application of this material can be made for 3.5 cents a box or a total of 5.5 cents.

**The following tabulation of an actual cost of operation in a 12-acre orchard of old but well-pruned trees presents some interesting facts as follows: The 12 acres of 770 trees with a full crop, yielding 11 boxes per tree, received an average of 13.5 gallons per tree for each spray. This was not a cheap operation as 6 sprays were applied consisting of a "pink" spray of lime sulphur and a regular five spray schedule for codling-moth control. Black leaf 40 was used in the pink and the fourth cover

**C. C. Griffin, Paonia, Colorado, 1929.

spray. Lead arsenate was used at the rate of 2 pounds to the 100 gallons with lime. The six sprays consumed 27 days for one man and team. The cost per picked box, counting all materials, including gas and oil, man and team labor, and depreciation on sprayer amounted to 8.91 cents per box, distributed as follows:

1.99 cents for lead arsenate.
3.41 cents for labor, gas, oil, etc.
2.25 cents for black leaf 40.
1.25 cents for lime sulfur.

This makes a total cost of 98 cents per tree or $62.44 per acre.

The method of spraying is not so important as the fact that there is a method in use. A system of spraying that will assure the complete coverage of the entire tree should be adopted and carried through consistently. Poor spraying is responsible for failure in codling-moth control more than any other factor and is one that can be corrected by careful study and observation. This is not often due to lack of effort but rather to a misinterpretation of what is really being accomplished in the work. It is easy to misjudge the carrying power of a spray stream and the coverage attained in the top of the tree. The operator should frequently interrupt operations long enough to thoroughly examine the inside and top of the tree to determine whether complete coverage has been obtained. A tree may be said to have four aspects in spraying; namely, the inside, the outside, the top above 6 feet and the lower portion below 6 feet. Of the four aspects, the top and the inside of the tree are the most difficult to spray. It has been the experience of the author to witness many conscientious operators who thoroughly sprayed the outside of the tree but failed to reach the top and inside portions.

The following system of spraying taken from Colorado Experiment Station Bulletin 322, is offered as a suggestion to those interested in the improvement of spray practice. While this particular system may not meet your requirements, it can be modified to fit in with any spray practice.

"**System in Spraying.**—Spraying is an operation that calls for the most careful thought. With the best of equipment and conditions, it is impossible to reach perfection. It should be looked upon as one of the most painstaking of all orchard operations and be very carefully studied and supervised. A definite system of work should be developed for each orchard. The details of such a system will, of necessity, vary somewhat with the different orchards and equipment, but so much poor work is a result of lack of any definite system of work that we are giving an outline of the procedure we have found useful. The procedure in approaching the trees is shown graphically in Fig. 5. The machine is driven down each side of the row and only one-half of each tree sprayed at a time. This includes the outer portion of the tree next to the machine and the inner portion of the opposite side. The operation is repeated upon driving back on the other side, and usually after the half of the tree treated first has had time to dry. If the rows are of such a distance apart that the man in the tower can reach two, some driving can be avoided by spraying on both sides of the machine, but usually with trees of much size, the man in the tower will need to be closer to the trees than this will permit. With the larger trees the machine should be stopped so the operator in the tower can spray the tree from at least three positions. The operator on the ground sprays from at least two or three positions near the trunk, and from four to six about the border of the half being sprayed. From each position all parts of the tree in direct view should be covered.

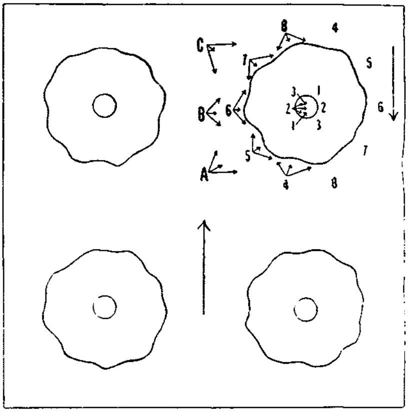

Fig. 5.—Suggesting a system of work in the orchard to develop thoroughness in spraying. The long arrows indicate the lines of movement of the machine. The man on the tower sprays from the positions of A, B, and C, and repeats from similar positions when the machine is on the other side of the row. The figures indicate the spraying positions of the man on the ground. See the text for a more complete description.

"The tower man sprays the entire top from each position and down upon all horizontal limbs. The ground man should first go to the center of the tree and take the positions as numbered, giving particular attention to covering the inner portions of the opposite side of the tree, then move to Position 4 and proceed with the spraying of the outer portions of the tree. The operators should make a careful study of the amount and character of the spray leaving the nozzles and so regulate the movement of the fan or cone of spray over a given portion of the tree that the proper coverage will be secured without respraying from that given angle. This will develop a slow movement of the nozzle in contrast to the more or less aimless whipping about of the spray which is too often seen and which leads to an under- or over-spraying of parts of the tree. Some prefer to spray the entire tree while the machine is on the one side, but it is impossible for the man on the top of the machine or on a tower to thoroughly cover the opposite side of the tree, and the ground operator finds it so much more difficult to reach all necessary spraying positions, that inferior work usually results."

In 1932 the application of spray from the ground alone gave as good control on the Delicious as from the top of the tank and the ground; however, in the case of the Rome Beauty the use of an extra man on the top of the tank gave only one-third as much wormy fruit as when operating from the ground alone.

It is important to give particular attention to the upper one-third of the tree, for from one-half to two-thirds of the eggs are laid in that portion. Codling-moth traps placed in the upper one-third of the tree catch twice as many moths as when placed in the lower one-third.

Summary and Conclusions

1.—In the North Fork Valley of Colorado and similar mountain districts, from 40 to 60 percent of the first-brood larvae transform to first-brood moths. In the Austin-Cory District the percentage transforming to first-brood moths averages 66, and in some seasons may approach a complete second brood.

2.—Broods are distinct and well separated in contrast with the overlapping of broods as in the Grand Valley.

3.—The moth population in the Austin-Cory District maintains a higher level than in the North Fork Valley.

4.—The districts of Montrose, Olathe, Redland Mesa, Cedaredge, Hotchkiss and Morrisiana, near the town of Grand Valley, have similar codling-moth activity as shown by trap records.

5.—The intensity of codling-moth infestation may vary from season to season and within a given orchard.

6.—To obtain the greatest value from cover sprays, it is essential to determine moth activity for each individual orchard and from it build a spray schedule to meet the problem.

7.—The use of lead arsenate is to be recommended in preference to any of the other materials which have been tested.

8.—A uniform coverage of lead arsenate can be obtained by the use of collodial spreaders and neutral soaps and is to be preferred to the spot type of coverage. To avoid excessive run-off the amount of spreader should be held to the minimum.

9.—Arsenical sprays other than lead arsenate are not recommended because of their inefficiency in control, and the danger of arsenical burning.

10.—Oil sprays in combination with lead arsenate have improved the control but should not be used beyond the second cover spray because of danger of oil injury and the increased difficulty in the removal of lead and arsenical residues.

11.—Oil sprays in codling-moth control have their greatest value as ovicides. They should be used at the peak of moth activity so as to come in contact with a large percentage of the eggs of the first brood.

12.—Mineral oils for summer sprays should be of a specific standard, manufactured by a reliable concern.

13.—Oil sprays should not follow delayed dormant or summer applications of lime sulphur closer than 30 days because of danger of burning.

14.—Oil sprays in combination with lead arsenate should not be allowed to stand in tanks or pipes.

15.—Supplemental measures of control such as banding, cultivation, screening of cellars, and the destruction of hibernating larvae are important.

16.—To obtain the best results from the use of bands it is essential that the trees be properly prepared by the destruction of all hiding places.

17.—Medicated bands are to be preferred to the untreated bands.

18.—"Hooch" traps as a supplementary measure of control have not proved of value but are of great value in determining moth activity.

19.—Thinning can be employed to remove wormy fruits and to facilitate better spraying by the breaking of clusters.

20.—Judicious pruning is essential to thorough spraying.

Acknowledgments

The author wishes to acknowledge the timely and valuable suggestions extended by Dr. C. P. Gillette, retired state entomologist of Colorado, under whose supervision it has been a privilege to serve during the major portion of the work herein reported. Also the help of Dr. Geo. M. List, state entomologist and entomologist of the experiment station, who inaugurated the work and gave much time to it in early years, and has been in direct charge of it at all times.

Acknowledgment is due those acting as temporary assistants in the life-history studies and experimental work, and to the following growers for their hearty cooperation in the experiments reported: C. Lund, George Ewing, J. W. Coe, Miss T. L. Hayward, Clyde Bryan, Evert Clark, Ernest Allen, A. L. Roberts, Merle Miller, and Charles Van Deren, deceased.