

CODLING MOTH IN THE GRAND VALLEY OF COLORADO

BY GEO. M. LIST AND WM. P. YETTER, JR.



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THE CODLING MOTH IN THE GRAND VALLEY OF COLORADO

BY GEO. M. LIST AND WM. P. YETTER, JR.

The control of the codling moth in the Grand Valley of Colorado has been a major problem of the apple and pear growers for a period of 25 or 30 years. It has constantly been growing more serious until at present the measures of control are the most expensive of all those performed by the growers, and the losses sustained are very heavy. The results determine the success or failure in the effort to produce these fruits. There seem to be few, if any, fruit-growing sections of the entire country where the problem is as serious.

Due to the uniform practice of spraying, and the certain disaster from leaving unsprayed trees as checks, there have been few opportunities to determine the degree of infestation in unsprayed orchards, but, under such conditions, a worm-free fruit is a rare exception, and there are usually on the average several worms per apple. For example, in 1914 there developed on 11 unsprayed trees under observation a total of 67,257 worms. As 1,200 fruits would be a good crop for an average tree, this means that there was an infestation of between 5 and 6 worms per apple. Many orchards show even greater infestations. In 1920 an orchard receiving 6 sprays, which were applied in a manner that would not be a discredit to any fruit-growing section, showed approximately 400 worms and 200 stings per 100 harvested apples. Probably an equal number had developed in the apples that fell to the ground and were not counted.

In 1923 another orchard receiving 6 sprays showed 505 worms and 756 stings per 100 harvested fruits. When it is realized that stings are almost invariably caused by the feeding of larvæ that later die from effects of spray poison, that many larvæ are poisoned without making "stings," and that, in these fruits that were practically 100 per cent free from calyx worms, probably 50 percent of the small larvæ had been poisoned at this point and could not be counted, it can readily be seen that placing the infestation at 2,000 worms per 100 apples would not be an exaggeration for such extreme conditions. In the latter orchard it was found by actual test that it was possible to count 100 eggs upon the leaves and fruit in less than one minute.

In another orchard that was receiving attention equal to what will give good control in many orchard sections, 100 apples picked at random had upon them a total of 606 hatched and unhatched eggs.

These serious conditions have naturally brought about undeniable demands for thorough and extended studies of the problem. This bulletin is not an effort to present in detail the results of several years of studies, but it is an effort to present in a rather concise form, certain data gathered and conclusions arrived at, that may be of immediate value to the growers. We wish it understood that, since the problem is in many respects a local

one, any recommendations or suggestions made are for this section only. The codling moth problem in other sections of the state is quite different and must be so considered.

DESCRIPTION OF VALLEY

Location and Topography.—The Grand Valley is located in the western part of Mesa County, on the western slope of the Rocky Mountain Range. It is approximately 32 miles long and 5 miles wide, and comprises about 80,000 acres of land of which nearly 8,300 acres are planted to fruit. Most of the fruit acreage is devoted to apples and pears, with the remainder chiefly in peaches, plums, cherries, apricots and bush fruits. The valley follows the course of the Colorado River and is rather level, except the Fruit Ridges. The Redlands and Orchard Mesa sections, although higher than the rest of the valley, are typical mesa lands. The elevation varies from 4,500 to 4,800 feet.

Climate.—The climate is rather dry, the annual rainfall being approximately 8 to 9 inches. From May to September, the season of development of the apple and codling moth, the precipitation amounts to only 3 or 4 inches. The mean normal temperature during this period is approximately 70.6 degrees Fahrenheit. Moisture is applied to the crops by means of irrigation systems, the water being supplied by the Colorado River. The day temperatures during the summer months are high, while those at night are relatively low.

STUDIES MADE

These studies on the codling moth in the Grand Valley were begun in 1914, and have been continued until the present time, with the exception of the season of 1920. Much time of the field men has naturally been taken in what might be considered service work among the growers. This has given an excellent opportunity to see thoroughly tried many theories and practices. The work has been supported jointly by the Colorado Experiment Station, and the Office of State Entomologist.

During the years of 1915 to 1919, inclusive, the work was in co-operation with the Office of Fruit Insect Investigations, Bureau of Entomology, United States Department of Agriculture. The results of life-history studies for 1915 and 1916 were published in United States Department of Agriculture Bulletin No. 932, "Life History of the Codling Moth in the Grand Valley of Colorado," and results of certain control experiments of 1916, 1917 and 1918 are recorded in United States Department of Agriculture Bulletin No. 959, "Experiments and Suggestions for the control of the Codling Moth in the Grand Valley of Colorado."

For the most part, the data for these years which are used in this paper, have been taken from these publications.

The senior author has been in general charge of the work since its inauguration and during the earlier years, especially, spent much time on

details of the work. The junior author has been in direct charge of the field station since 1921. We are indebted to Mr. Claude Wakeland, who was stationed in the valley during the seasons of 1914 and 1915, and to Messrs. H. L. Sweetman, Carl A. Bjurman, Raymond Roberts and G. A. Schenck, who did a considerable portion of the insectary work during the seasons of 1922, 1923, 1924 and 1925, respectively.

Mr. L. E. Jaynes and Otto M. Forry, county horticultural inspectors for Mesa County, have offered many valuable suggestions and helped in many ways.

The general plans of work were made after consultation with Dr. C. P. Gillette, State Entomologist, and Director of the Experiment Station.

RESUME OF LIFE HISTORY AND SEASONAL HISTORY

Since there is often a certain amount of confusion resulting from a misunderstanding of terms used in discussing insects and their development, it seems advisable to give the definition of a few terms as herein used.

The term "stages" refers to the four distinct periods of development through which all insects belonging to the same order as the codling moth pass: egg, larva, pupa, and adult or moth.

The term "generation" is used to include all four stages of any group of insects descending from a specific insect or group of insects. It is understood to begin with the egg stage and terminate with the adult.

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

The term "brood" is used in speaking of individuals of any stage of one generation, as brood of eggs, brood of pupæ, etc. The terms "first brood," "second brood," etc., are used to designate the generation to which the eggs, pupæ, larvæ or adults may belong.

"Transforming larvæ" are those that transform to pupæ and adults the same season they hatch, while "non-transforming larvæ" are those that do not make this development until the following season.

In the Grand Valley, a limited number of the first-brood larvæ, a considerable percentage of the second, and all the third brood are non-transforming. Hence the over-wintering larvæ represent three generations and to avoid confusion are spoken of as "wintering" or "spring-brood" larvæ, and the pupæ and adults into which they transform, as "spring-brood" pupæ and moths.

By "seasonal history" is meant the entire seasonal development of an insect regardless of the number of generations. With the codling moth, the number of generations during a season may vary with different localities or seasons. In some localities there is only a single generation, while under other conditions, there may be as many as three to five. Under the

Grand Valley conditions the seasonal development gives us the following:

1. The over-wintering larvæ. These include all nontransforming larvæ, and represent the first, second and third broods of larvæ of the previous season.
2. The spring brood of pupæ.
3. The spring brood of moths. These are usually spoken of as first-broods moths, but since they have developed from larvæ representing different generations, it is less confusing to speak of them as spring-brood moths, and consider the first generation to begin with the eggs.

The first generation:

1. The first-brood eggs.
2. The first-brood larvæ. A limited number of these will not develop into moths to form another generation the same season, but will carry over until the next season as wintering first-brood larvæ.
3. The first-brood pupæ.
4. The first-brood moths, often spoken of as summer-brood moths.

The second generation:

1. The second-brood eggs.
2. The second-brood larvæ. A considerable percentage of these are nontransforming larvæ. The percentage transforming varies with different seasons.
3. The second-brood pupæ.
4. The second-brood moths.

The third generation:

1. The third-brood eggs.
2. The third-brood larvæ. All of these are nontransforming larvæ.

It will be seen that some individuals go through only one generation in a season, while others go through two, and still others through two stages of a third generation. It is known that temperature is a big factor in determining the number of generations, but it does not appear to be the only one, as many of the nontransforming first-brood larvæ enter their over-wintering cocoons during very warm weather, and remain inactive during a considerable portion of the season, while some others are passing through a second and even a third generation.

The difference in the individuality and the many conditions under which the insect is found, especially during hibernation, tends to extend the appearance of the individuals of any one brood over a considerable period, with the result that there may be an overlapping of the broods. The heavy infestation that is brought about by the favorable codling moth conditions almost presupposes a greater spread in the appearance of the

individuals making up any one brood. The larger the number concerned, the greater is the spread in their development and appearance. The appearance of the different broods of the first generation is more distinct than with the second and third, but there is no time throughout the season that eggs or newly-hatched larvæ cannot be found. The second and third broods can be separated only with difficulty. This overlapping greatly complicates the work of control, making it necessary to provide considerable protection to the fruit at all times. However, regardless of this overlapping, there are definite times when the different broods are at their height. It is important that these periods be definitely determined so that control work can be the most effectively planned.

DESCRIPTION OF STAGES AND HABITS

Success in controlling this insect under Grand Valley conditions can hardly be attained by any one method of attack. To be successful, fruit growers should be able to recognize the codling moth in all stages and be familiar enough with its life history and habits that they can take advantage of all practical means of control.

The Egg.—The egg is circular in outline, flat, measures from 1 mm. to 1.25 mm. in diameter, which is somewhat less than the diameter of an ordinary pin head, and is pearly-white to semitransparent when first deposited. On the second or third day, during warm weather, a red ring, which is an early embryonic stage of the larva, can be seen through the shell, and one day before hatching the black head of the larva appears as a black spot. At this time, by means of a hand lens, the outline of the coiled larva can be distinguished. After the larva has hatched, the shell remains as an almost transparent glistening speck.

Early in the season, the majority of the eggs are placed upon the upper surface of the leaves near the fruit but later the surface of the fruit seems to be preferred. They are only occasionally deposited on the twigs, stems and under surface of leaves. The larvæ hatch by breaking a small exit hole in the upper portion of the shell. They never go directly into the fruit from the egg.

Larva.—The newly-hatched larva is about one-sixteenth of an inch in length, with a light flesh-colored body and dark brown head. The mature ones are about three-quarters of an inch in length with much the same color.

The newly-hatched larvæ may crawl about for several minutes or even several hours and feed in a limited way upon the leaves, but they usually make an early entrance into the fruit. It is easier for them to make entrance at a point where two apples, or a leaf and an apple are together, or at a roughened place on the fruit. The calyx is a favorite place. Counts show that from 25 to 80 percent of the first brood enter at this point, the percentage varying with varieties of fruit and conditions. The second

and third-brood larvæ enter largely through the sides. Several may enter a single fruit, but they are somewhat cannibalistic, which tends to keep down the number maturing in a single fruit.

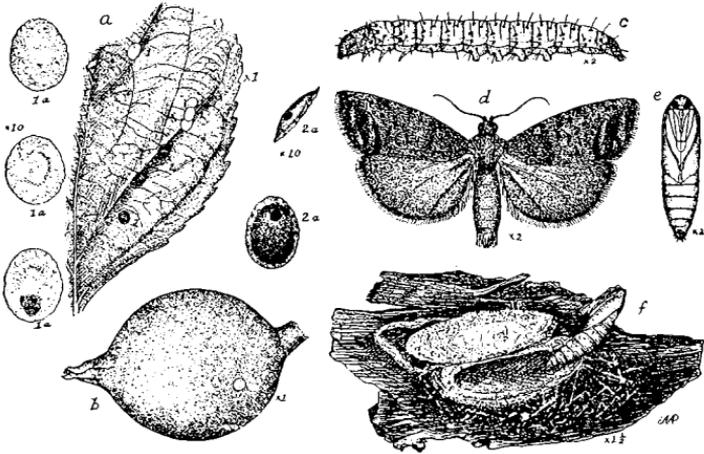


PLATE I. Codling Moth in its different stages: a, eggs upon a leaf; 1 a, eggs natural size; 1 a, eggs much enlarged; upper 1 a, a newly laid egg; middle 1 a, the appearance of the egg after 4 or 5 days, showing the flesh-colored ring of the embryo, lower 1 a, showing the outline of the small larva, the dark spot being the head (an egg in this stage would hatch in a day or two); a 2, eggs parasitized by *Trichogramma minutum*, a very small 4-winged fly that deposits its eggs within those of the codling moth; 2 a, parasitized codling moth eggs much enlarged, showing holes made by the parasites as they leave the eggs; upper 2 a, side view of parasitized egg; b, egg natural size upon an apple; c, codling moth larva; d, codling moth; e, chrysalis or pupa; f, cocoon and chrysalis. Figures a1 and a2 and b, natural size; 1 a and 2 a, enlarged 10 times; c, d, and e, enlarged 2 times; f, enlarged $1\frac{1}{2}$ times. Original. Colorado Experiment Station Bulletin 210. Miriam A. Palmer, Designer.

The mature larvæ usually leave the fruit before it falls as a result of the injury, and crawl down the tree in search of suitable places to spin cocoons.

The Cocoon and Pupa.—The insect transforms from the larva to the adult moth in silken cocoons. These are formed of silken threads and small bits of bark and wood. The cocoons made by the over-wintering larvæ are much heavier and afford much more protection than those of the transforming. The cocoons are spun in most any place where the larvæ can crawl between two surfaces and feel a contact, or they may cut out a small oval cavity where a crevice is not to their liking, and interweave the pieces of bark and wood into the cocoon. Choice locations are under loose bark on the limbs and trunk, in the crotches of trees, in split or decayed limbs, in rubbish in the crotches of limbs or on the ground about the tree, in crevices of picking and packing boxes, packing sheds, in hollow stems of plants under the tree, and to some extent in cracks in the soil, especially immediately surrounding the tree trunk. It is thought that the number going into the soil under the dry conditions that exist in the Grand Valley

is greater than in the more humid sections. This has a direct bearing upon the development of the insect as the greater protection influences the winter mortality and the great variety of conditions influences the spring development and causes a greater spread in appearance of the spring brood.

The larvæ, especially the over-wintering ones, may move and build new cocoons before pupation is begun, if their locations are not to their liking. Immediately before pupation, all remodel their cocoons by building a small silken exit tube to insure the exit of the moth. If the cocoons are exposed or under a protection such as a cloth band, through which the pupæ can push, these tubes will be very short, but, if by chance the larvæ became buried, the tubes may be of considerable length, but usually, if it is necessary for the tubes to be more than a fraction of an inch, new cocoons are built in a more advantageous position.

A good portion of a number of larvæ buried from 4 to as much as 10 inches in the soil by the junior author, were able to make their way to the surface, thus showing the little likelihood of material control by plowing under larvæ in rubbish, fruit, etc.

The pupæ are at first light yellow in color, becoming darker as they develop, until they are a mahogany brown just before the moths emerge. They resemble a cigar in shape, being somewhat thicker at the head end, and about one-half inch long. Just before the moth emerges, the chrysalis breaks the thin silken partition between the cocoon and the exit tube, and wriggles out through the exit tube, attaches by hooks on the anal end, and the enclosed moth breaks the pupal case and emerges. The brownish-colored pupal cases, as they protrude through the bands or from the old cocoons under the bark, are familiar to all.

The Moth.—The dark gray coloring of the moth so blends with the surroundings that it is not readily seen. The dark gray wings are crossed with darker lines, and near the tip of each forewing is an irregular golden spot. The wing expanse varies from five-eighths to three-quarters of an inch. When at rest the wings are folded backward over the body.

The moths are most active about dusk and are never seen flying during the day unless the trees are disturbed as by spraying, when they may be seen fluttering from one limb, or occasionally from one tree, to another. When at rest they are usually on the shady side of a leaf or limb. They are not strong flyers. It is possible that they may, under certain conditions, travel a mile or more during their lives, but the number traveling such distances is very small. There is ample proof that the natural dispersal carries the adults a distance of several rods into adjoining orchards, thus making a poorly cared for orchard a menace to those near by.

Seasonal History

Certain seasonal history studies of the codling moth were made in the Grand Valley during the seasons of 1914, 1915, 1922, 1923, 1924, 1925 and 1926.

It would be impractical and unnecessary to attempt to give the data collected in these studies in detail, so only the points having the most direct bearing upon the control work and those most frequently brought up by questions from the growers will be discussed.

Many of the essential facts have been presented to the growers from time to time in the form of lectures and short articles, and the data have been the basis for the spray programs recommended during these several years.

The tables and graphs presenting data on the various stages should be considered separately, as it is impracticable to carry the same individuals through all the stages, and from the standpoint of studying the conditions as they develop in the orchard, it is advisable to go to the orchard for new material for certain studies. Thus the spring brood of moths was reared from the over-wintering larvæ collected as they left the fruit during the summer and fall, while the first and second-brood moths, instead of coming from breeding-cage progeny of the caged moths, were reared from first and second-brood larvæ taken daily from unsprayed trees. They are therefore thought to represent a more accurate cross section of the development within the orchard.

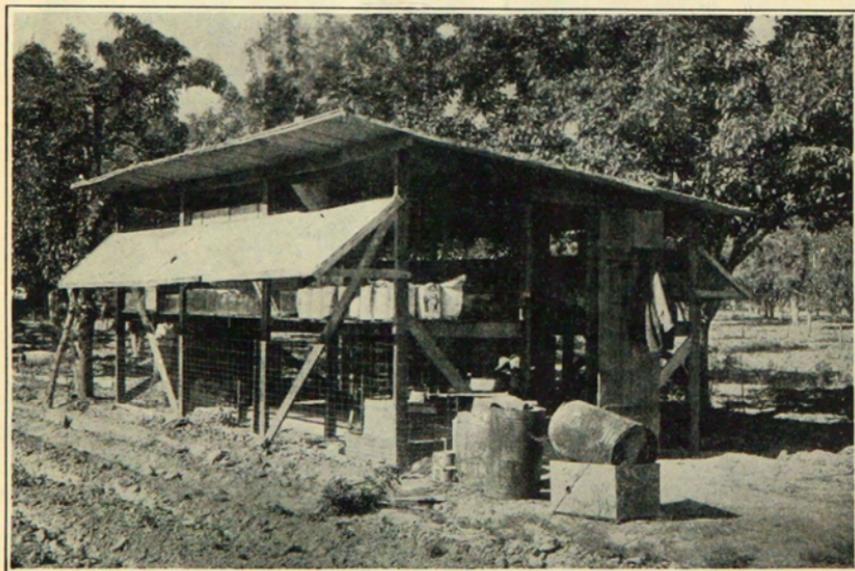


Figure 1.—The laboratory in which the codling moth life-history data were taken.

The first spring activity is in the form of the necessary remodeling or rebuilding of the cocoons by the over-wintering larvæ so the moths will be able to make their exit. This is very seldom noticed unless the larvæ are being closely watched.

PUPAE OF THE SPRING BROOD

The exact dates of pupation and the length of the pupal stage of this brood have little direct bearing upon any of the operations for control, so have not been carefully studied all the years. In 1915 the earliest date of pupation was April 14 and the last date, June 8. The average length of the pupal period for 233 individuals was 27.58 days, the maximum 34 days, and the minimum 15 days. In 1916 the earliest date of pupation was April 16, and the latest, June 12. The average length of the pupal period of 390 individuals was 26.80 days, the maximum 36 days, and the minimum 13 days.

SPRING BROOD MOTHS

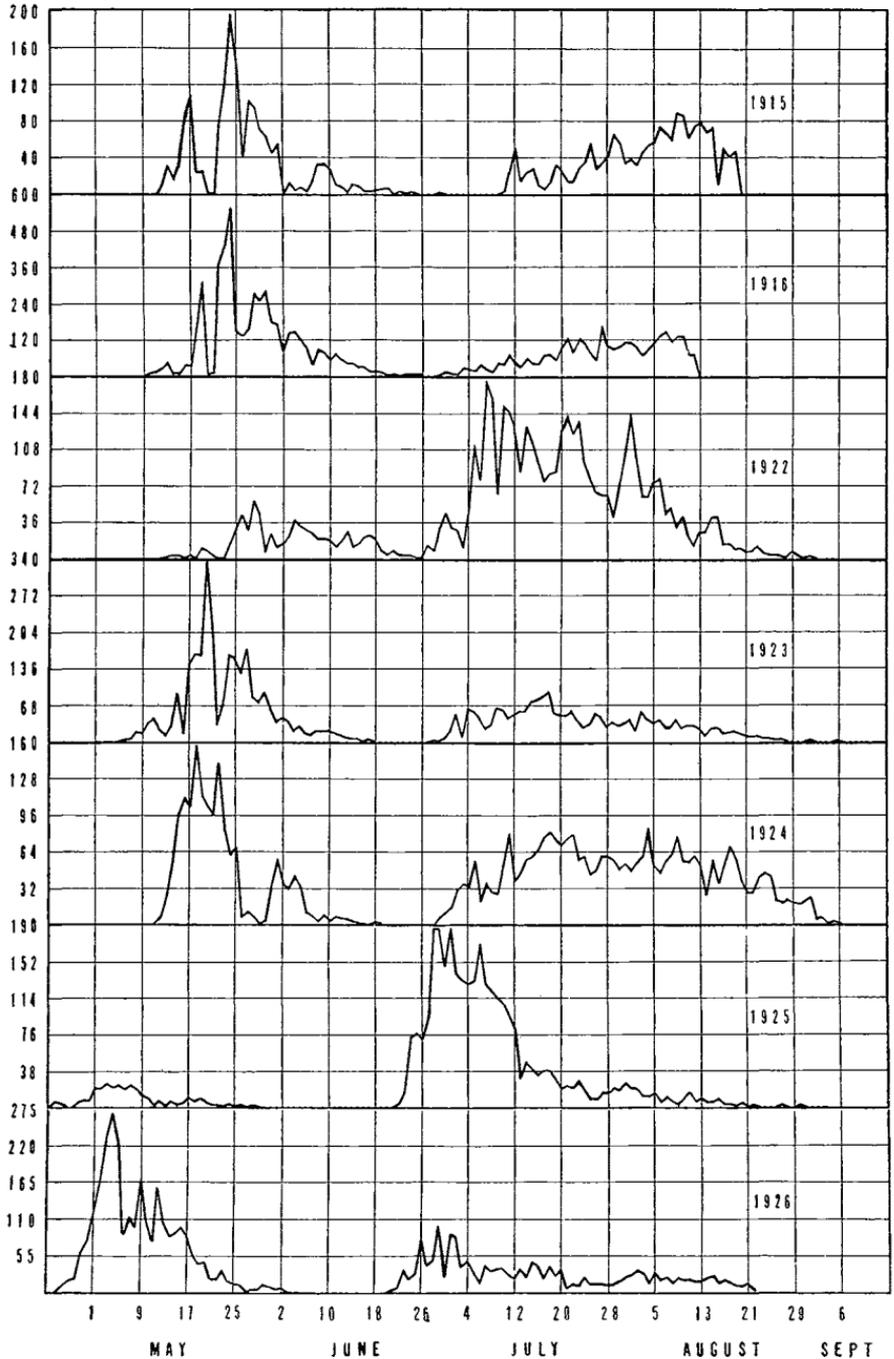
Time of Emergence.—A complete moth emergence record has been taken each year from a large number of over-wintering individuals. These have been used in securing the egg deposition record from which the spray dates have been determined. The complete record includes 14,196 moths. The first date, last date, and dates of maximum emergence are given in Table 1, and the daily emergence is shown graphically in Plate 2. It will be noted that there is a considerable seasonal variation. The earliest date for emergence was April 24, 1925. The latest date for emergence to begin was May 13, 1922. In contrast with this, in 1926, 76.39 percent of the spring brood moths had emerged by May 13, and in 1925, 74.69 percent.

Table 1.—Emergence of Moths of the Spring-brood, Grand Junction, Colo.

Year	First Moth	Last Moth	Period of Moth Emergence	Maximum Moth Emergence	Total Moths
1915	May 12	June 29	48 days	May 17—May 27	1,539
1916	May 10	June 28	49 days	May 19—May 29	4,808
1922	May 13	June 29	47 days	May 25—June 6	672
1923	May 6	June 22	47 days	May 17—May 28	2,604
1924	May 11	June 19	39 days	May 14—May 25	1,542
1925	April 24	June 8	46 days	April 30—May 10	328
1926	April 26	June 5	43 days	April 28—May 24	2,703
Total					14,196

In 1926, emergence of moths was completed by June 5, while in 1915 it continued until June 29, or 24 days later by the calendar. It will be seen by Table 1 and Plate 1 that the period of maximum emergence is just as variable. In 1916 and 1922, it can be considered as beginning May 19 and 25, respectively, while in 1925, it was over by May 10. The period of moth emergence varied in length from 39 days in 1924, to 49 days or 7 weeks in 1916. Orchard observations and other studies indicate that the entire period of emergence in the orchard and vicinity is somewhat longer than this, due to the delayed emergence of those that hibernate in cellars, packing houses and other protected places, but the records seem to be very typical of the early and maximum emergence.

PLATE 2.—Codling-Moth Emergence Records



Sexes of the Spring-Brood Moths.— Of 11,960 spring-brood moths handled, 5,525 or 45.4 percent were males, and 6,435 or 54.60 percent were females. The early moths to emerge are usually males. Taking 1923 as a typical year, the records show that, of the first 21 moths to emerge, 18 were males, and during the first 10 days of the 45 days of spring-brood moth emergence 15.89 percent of the season's males emerged, while during the same period only 8.55 percent of the females emerged. This same year 50 percent of the males and only 38.34 percent of the females had emerged by May 21.

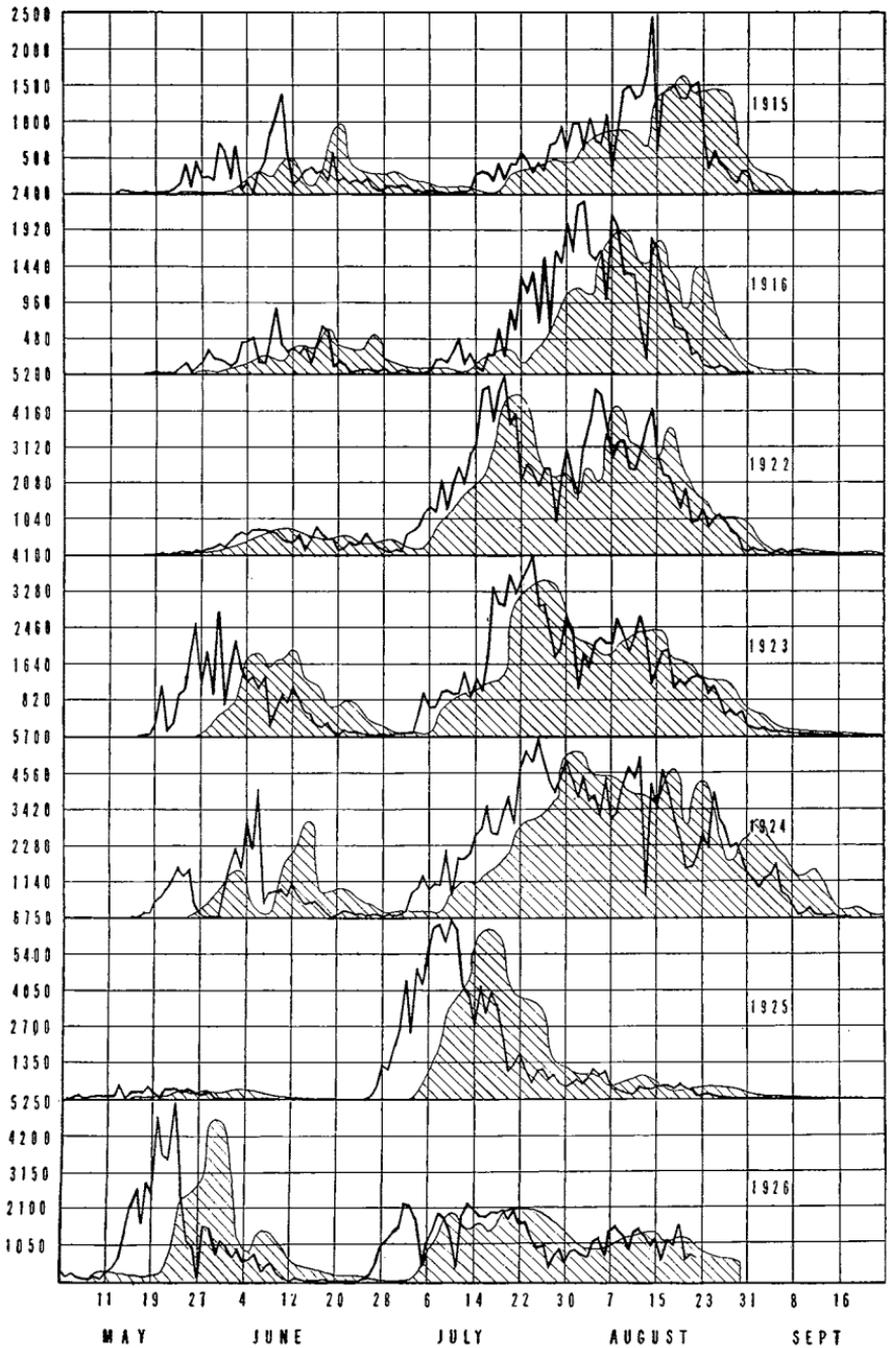
Oviposition by Moths of the Spring Brood.— Oviposition records were obtained on the spring-brood moths. The oviposition cages in which the moths were confined consisted of glass battery jars, 6 by 8 inches, the bottoms of which were covered with a 2-inch layer of moist sand. The top of the sand was completely covered with a disk of blue blotting paper to keep the moths off the sand, and to facilitate counting eggs and cleaning the jars. About 25 moths were placed in each cage with a small sponge saturated in sweetened water. A small pear twig of foliage was placed in each cage daily. The time from emergence until oviposition begins, varies. For instance, in 1923 the female moths that emerged on May 8 did not deposit eggs until May 19, or 11 days later, while those emerging on May 29, June 14 and 17, deposited eggs the next day. The average length of time before egg deposition began for this same year was 3.96 days. The length of the oviposition period ranged from 7 to 27 days, with 18 days as the average. The greatest egg deposition occurs between 3 and 9 p. m. The temperature during this period is the most important controlling factor. Few eggs are deposited when the average temperature for this period is below 60 degrees Fahrenheit.

PLATE 2.—Showing graphically the daily record of the emergence of the codling moth at Grand Junction, Colorado, during seven seasons. The emergence of a total of 14,196 spring-brood moths, and 21,764 first and second-brood moths, is recorded. The first part of the graph for each year represents the spring brood, while the second part represents the first and second broods combined, with the exception of the graph for 1915 and 1916, when August 19 and August 13 were arbitrarily selected as the dates for the completion of the emergence of the first brood, and the second-brood records were omitted. The larvae from which the spring-brood moths were reared, were collected the previous season and wintered under natural conditions. Those forming the first and second-brood moths were collected daily from bands on unsprayed trees. The sudden fluctuations in the number emerging are due to changes in temperature conditions. These are the most noticeable in case of the spring brood. At no time was there an overlapping in the emergence of the spring and first-brood moths, but the first and second broods overlap to such an extent that it is difficult to separate them. The earliest date of emergence was April 24, 1925, and the latest date for spring-brood emergence to begin was May 13, 1922.

It will be noted that the peak of spring-brood emergence during 1925 and 1926 was reached at an earlier date than the first emergence during four of the other years. The peak of emergence came 22 days later in 1922 than in 1926. Spring-brood emergence was completed by June 5 in 1926, and not until June 29, or 24 days later, in 1915.

The earliest date of first-brood moth emergence was June 21 in 1925 and 1926. In 1915 this emergence did not begin until July 9. First and second-brood moth emergence continued over a period of 89 days in 1924, the latest date of emergence being September 26. The period of maximum first and second-brood emergence usually occurs during the latter part of July and the fore part of August, although in 1925 and 1926 it occurred during the last days of June and early in July.

PLATE 3.—Codling-Moth Egg Records



Eggs per Female Moth.—The spring-brood moths deposited on an average of 23.12 eggs per female as shown in Table 2. The lowest average was in 1916 with 11.34 eggs, and the highest in 1924 with 46.07 eggs.

Egg Deposition During the Life of the Moths.—The egg deposition during the life of the spring-brood moths of 1923 is shown in Figure 2. It is quite typical of the other seasons. Eggs were deposited on the first and twenty-ninth days after emergence, with the maximum deposition occurring on the seventh day, which would be the eighth day during the life of the moth.

Table 2.—The Average Number of Eggs Deposited per Female Moth, Grand Junction, Colo.

Year	Spring Brood	First and Second Broods
1915	12.59	46.73
1916	11.34	43.98
1922	33.30	75.78
1923	28.12	91.58
1924	46.07	130.04
1925	36.76	72.01
1926	36.21	98.44

Length of Life of the Spring-Brood Moths.—The average, maximum and minimum lengths of life of the male and female moths is shown in Table 4. The average for the males ranged from 13.04 days in 1922, to 18.41 days in 1925, and of the females from 11.93 days in 1922,

Table 3.—A Summary of the First-brood Egg Deposition, Grand Junction, Colo.

Year	First Egg	Last Egg	Period of Egg Deposition	Maximum Egg Deposition	Total Eggs
1915	May 13	July 8	56 days	May 24—June 25	14,359
1916	May 19	July 7	49 days	May 27—June 20	16,435
1922	May 14	July 9	56 days	May 30—June 27	14,688
1923	May 16	July 5	50 days	May 20—June 18	33,524
1924	May 15	July 3	49 days	May 19—June 16	33,219
1925	May 4	June 19	46 days	May 6—May 29	5,588
1926	April 29	June 23	55 days	May 13—June 10	48,624
Total					166,437

PLATE 3.—The heavy solid lines show graphically the daily deposition of codling moth eggs during 7 seasons, while the lighter, unbroken lines, enclosing the crosshatched areas, represent the daily hatching of larvae. A total of 878,461 eggs are represented. The taking of records for 1926 was discontinued August 30. The sudden fluctuations in the records are due almost entirely to changes in temperature. The earliest date of deposition was April 29, 1926, the latest date for the first eggs of the season was May 19, 1916. There is a similar difference in the time of the maximum deposition of the first-brood eggs. The latest date of first-brood egg deposition was July 9, 1922. In contrast with this it will be noted that the last of the first brood eggs for 1925 were deposited as early as June 19. The length of the first-brood egg-laying period is approximately 50 days.

The deposition of second and third-brood eggs is shown in the latter part of the graph for each season. These two broods were not separated. The earliest date for second-brood eggs to occur was June 24, 1926, while in 1916 the first did not appear until July 11. The latest date of deposition was October 6, 1925. In 1925 there was a second and third-brood egg-laying period of 102 days.

The earliest date of hatching of larvae was May 15, 1926. In 1916 the first larvae appeared June 1. First-brood larvae continued to hatch until in July each season except during those of 1925 and 1926.

The first of the second-brood larvae hatched on July 4, 1925, and 1926, and hatching of the second and third-brood continued well into September each year. The maximum hatching usually occurs during August, although it occurred during July for the years of 1925 and 1926. There are larvae hatching at all times throughout the season.

to 17.24 days in 1924. During five of the seasons, the average for the females slightly exceeded that of the males. The maximum length of life for the males varied from 34 days to 39 days, and for the females, 29 days to 39 days. The average of the seasonal maximums of the males is 3 days greater than that of the females. As a general rule, however, it could be said that the females slightly outlive the males.

FIRST GENERATION

Eggs of the First Brood

Time of Deposition.—A cross section of the actual deposition of a brood of moths gives about as definite knowledge of the insect development for the timing of the spray applications as is available. This record has been the most valuable of those made. Table 3 gives the first and last dates, and the dates of the maximum egg deposition of the spring brood of moths for seven seasons.

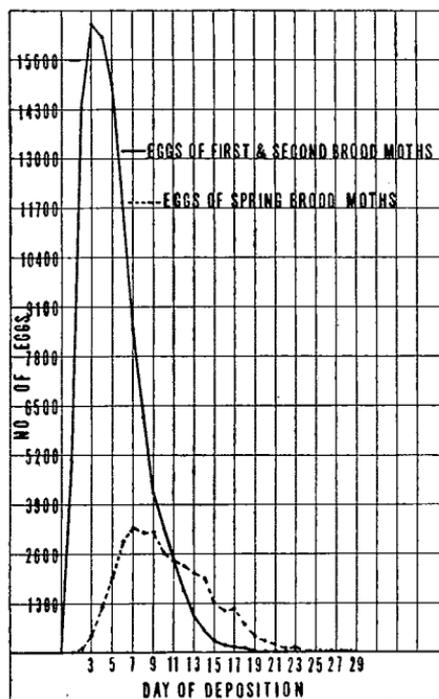


Figure 2.—The broken line shows the egg deposition during the life of the spring-brood moths for 1923. It will be noted that the greatest deposition occurred on the seventh day. It began on the third day and continued until the twenty-ninth.

With the second-brood moths, deposition began on the first day after emergence and reached the height on the third day. The season of 1923 was quite typical of the others.

The daily egg deposition for these same reasons is shown graphically in Plate 3.

The earliest date of egg deposition was April 29, 1926, and the latest for first egg deposition for any season was May 19, 1916, or 21 days later. The latest date for first-brood egg deposition was July 9, 1922, while in 1925 the last ones were deposited June 19. It will be noticed that the seasons of 1925 and 1926 were much earlier than the others. The season of 1926 was the only one in which eggs were deposited in the month of April.

The period of deposition varied in length from 46 days in 1925, to 56 days in 1915 and 1922, with an average of 51.5 days. It is probable that under orchard conditions this period is somewhat longer.

Table 4.—The Length of Life of Male and Female Spring-brood Moths, Grand Junction, Colo.

Year	Sex	Average Days	Maximum Days	Minimum Days
1915—	Male	14.59	36	1
	Female	15.86	39	1
1916—	Male	14.67	35	1
	Female	15.75	39	1
1922—	Male	13.04	37	1
	Female	11.93	29	1
1923—	Male	13.95	36	1
	Female	14.33	32	2
1924—	Male	17.08	34	1
	Female	17.24	31	1
1925—	Male	18.41	39	1
	Female	17.10	30	1
1926—	Male	15.59	39	1
	Female	16.52	36	1

The period of maximum deposition as given in Table 3 has been approximated from the daily egg deposition as shown in Plate 3. It is interesting to note that it usually takes place during the latter part of May and the fore part of June; however, in 1925, it took place entirely in the month of May. That year it was over by May 29, while in 1922, it did not begin until May 30. The date of the greatest first-brood egg deposition, for each year, with the number of eggs, is as follows:

1915—	June 10	1,380	Eggs
1916—	June 9	885	Eggs
1922—	June 16	822	Eggs
1923—	May 30	2,795	Eggs
1924—	June 6	4,006	Eggs
1925—	May 20	366	Eggs
1926—	May 23	5,241	Eggs

It is interesting to note that on June 6, 1924, 11.3 percent of the first-brood eggs were deposited, although the deposition continued over a period of 49 days.

The daily egg deposition as shown in Plate 3 is very interesting. The sudden fluctuations are due to changes in temperature. In some cases these are of such extended duration that the reduction in the number of eggs is enough to have a bearing on the spray program. This is true for June 2 to 7, 1915, and May 26 to 31, 1924. In each of these cases, a sudden checking of the oviposition occurred just at the time the maximum would have been reached under favorable conditions. During the period of May 26 to 31, 1924, the temperature between 3 and 9 p. m. each day was at all times below 60 degrees F., while on May 28, 29 and 30, when no eggs were deposited, it never reached 55 degrees.

Incubation Period.—Each day during the period of egg deposition a sufficient number of eggs was selected for studies on the incubation to give an accurate record on this stage of development. It is from these data that the hypothetical curve of the egg hatching as shown in Plate 3 was constructed. The average, maximum and minimum of the incubation

period for the seven seasons are given in Table 5. It will be noted that the average ranged from 5.82 days in 1922, to 10.73 days in 1925. The maximum of 9 days for 1922 was less than the average for 1915, 1924, 1925 and 1926. The greatest maximum was 15 days and occurred with eggs that were deposited during, or just before, a period of cool weather. Usually the early eggs of the season have a period of incubation that is considerably longer than the average on account of the cooler weather. The lowest minimum occurred during 1924 when a considerable number of eggs hatched on the fourth day. In 1925, no eggs hatched in less than 7 days.

The orchardists, in their calculations for control work, should consider the incubation period during normal weather as 5 or 6 days.

Table 5.—The Incubation Period of First-brood Eggs, Grand Junction, Colo.

Year	Average (Days)	Maximum (Days)	Minimum (Days)
1915	9.14	15	6
1916	7.32	14	6
1922	5.82	9	5
1923	8.90	12	6
1924	9.61	15	4
1925	10.73	13	7
1926	9.50	15	6

Larvae of the First Brood

Time of Hatching.—The hatching of the first-brood larvæ is shown graphically in Plate 3. Table 6 gives the first and last dates for hatching. The date of earliest hatching was May 15, 1926, and the latest date for the hatching for any season was June 1, 1916.

The first-brood hatching continued into July each year except 1925 and 1926, when it stopped on June 10 and 17, respectively. The latest date for the hatching of first-brood larvæ was July 13, 1915. The length of the hatching period varied from 26 days in 1925, to 52 days in 1915. From Tables 6 and 12, it will be noted that first-brood hatching during 1922 continued until the second-brood hatching began, and in 1916 it continued 2 days later. Under orchard conditions, there is always an overlapping of these broods.

Length of Feeding Period.—Data were not taken on the length of the feeding period each season. During 1915, 758 larvæ of the first brood showed, when carried in the insectary, an average feeding period of 21.64 days, maximum 35 days, minimum 12 days. The same year 242 larvæ feeding in bagged fruits on the tree gave an average feeding period of 22.73 days, maximum 35 days, minimum 15 days.

In 1916, the feeding period of 817 first-brood larvæ in the insectary was, average 20.19 days, maximum 42 days, minimum 14 days, and of 264 fed in bagged fruit on the trees, average 21.10 days, maximum 29 days, and minimum 17 days.

Time of Maturity.—It is unnecessary to give in detail the time of maturity of the first-brood larvæ as shown by band records made during

the several years, but from the standpoint of using bands, it is important to know the earliest dates larvæ may be leaving the fruit. These are as follows: 1914, June 5; 1915, June 22; 1916, June 17; 1919, June 5; 1922, June 12; 1923, June 13; 1924, June 14; 1925, June 10; 1926, June 6.

**Table 6.—The Time of Hatching of First-brood Larvæ,
Grand Junction, Colo.**

Year	First Hatching	Last Hatching	Length of Hatching Period in Days
1915.....	May 27	July 13	52
1916.....	June 1	July 11	41
1922.....	May 28	July 7	41
1923.....	May 28	July 3	37
1924.....	May 24	July 1	38
1925.....	May 16	June 10	26
1926.....	May 15	June 17	34

Pupæ of the First Brood

Length of the Cocooning Period.—The cocooning period is considered as extending from the time the larvæ leave the fruit until they take on the form of the pupæ. It is of only general interest here. In 1915, the average for 430 individuals was 6.7 days, maximum 28 days, minimum 1 day. In 1916, the average for 761 larvæ was 5.53 days, maximum 30 days, and minimum 2 days.

Length of Pupation Period.—The average pupation period of 331 pupæ of the first brood in 1915 was 11.44 days, maximum 31 days, minimum 6 days, and of 638 individuals in 1916, average 11.23 days, maximum 19 days, and minimum 6 days. The combination of the cocooning and pupal periods is of more importance to the fruit grower, as this determines the frequency with which bands must be removed during the period when transformation takes place. During extremely favorable weather, a very limited number have made their cocoons and transformed to moths in 8 days, and in ten days this number is considerable. All bands should be removed on the tenth day, and during the warmest weather it is desirable to remove them on the ninth.

Moths of the First and Second Broods

Larvæ were collected from bands on unsprayed trees each day throughout the season and used as the source of supply for the later breeding material. It is therefore impossible to separate definitely the first and second broods, so the two are considered together.

Time of Emergence.—Plate 2 shows graphically the emergence of moths. This includes the emergence of the spring brood and the first and second-brood moths for each year, with the exceptions of 1915 and 1916, when the record of the second brood was omitted. Table 7 gives the dates of first and last moth emergence, and the length of the emergence period for the first and second brood. The data given for 1915 and 1916

is not the same as that use in making the moth emergence graph shown in Plate 2.

Table 7.—The Time of Emergence of Moths of the First and Second Brood, Grand Junction, Colo.

Year	First Moth	Last Moth	Period of Moth Emergence (Days)	Maximum Moth Emergence	Total Moths
1915	July 9	Sept. 8	61	July 25-Aug. 15	3,509
1916	June 25	Sept. 8	75	July 20-Aug. 10	4,378
1922	June 26	Sept. 1	67	July 5-Aug. 2	3,959
1923	June 28	Sept. 6	70	July 2-Aug. 5	2,180
1924	June 29	Sept. 26	89	July 4-Aug. 24	3,059
1925	June 21	Sept. 2	73	June 24-July 18	3,020
1926	June 21	Aug. 22	62	June 23-Aug. 17	1,659

Total, 21,764

The earliest date of first-brood moth emergence was June 21 in 1925 and 1926. In 1915 the first moth of this brood did not appear until July 9. In general, it can be said that emergence begins during the latter part of June. The period over which first and second-brood moth emergence occurs is quite extended. The longest was 89 days in 1924, and the shortest 61 days in 1915, average 71 days.

The laboratory was closed August 22, 1926, and moths were still emerging, hence this does not represent the seasonal limit. It will be noted that emergence continued into September each of the other years. The latest emergence occurred September 26, 1924. The period of maximum emergence can be said to usually occur during the latter part of July and fore part of August, yet in 1925 and 1926, it began in June and in 1926 it was over by July 18. This was an early season with rather cool weather during late summer.

Sexes of the Moths.—The moths of the first and second brood were more evenly divided as to sexes than those of the spring brood. Of 18,337 moths handled, 8,847 or 48.3 percent were males, and 9,490, or 51.7 percent females.

Oviposition by Moths of the First and Second Broods.—The oviposition record has been taken on 18,923 first and second-brood moths. These moths begin to lay eggs more quickly after emergence than the spring-brood moths. A large percentage of the cages showed eggs within one day. The average time before egg deposition for 1923, which is a representative season, was only 1.3 days, and maximum, 3 days. The average period of oviposition for 91 cages this same year was 14.54 days, maximum 23 days, and minimum 6 days.

Eggs per Female Moth.—Table 2 gives the average egg production per female moth for the different seasons. It will be noted that during most years it was about three times that of the spring brood. The lowest average was 43.98 in 1916, and the highest 130.04 in 1924.

It is likely that few moths lay their full quota of eggs. Since a number of moths were carried in each cage, it is impossible to know the maximum

individual production. In a number of instances, pairs were confined in a single cage with the result that the egg production was found to vary from nothing to as high as 316 eggs for one female. A production of 150 to 285 per female was common, but few reached the 300 mark. Counts made on dissected mature females by the senior author showed that the possible production would range from 300 to 340. There was no difference between the moths of the different broods, so the variation in egg deposition is due to environmental conditions. It is possible that under orchard conditions the egg production may run higher than in cages. Temperature seems to be the most important controlling factor.

Eggs Deposited During the Life of the Moth.—Figure 2 shows the total deposition on specified days of all first and second-brood moths during the season of 1923. It will be noted that eggs were deposited freely on the first day after emergence, which is the second day of the life of the moth. The maximum deposition occurred on the third day, and the last deposition on the twenty-fifth day after emergence.

Length of Life of First and Second-Brood Moths.—The average, maximum and minimum lengths of life of the males and females is given for each of the years in Table 8. The greatest maximum for the males was 47 days, and for the females 45 days, both of which occurred in 1925. The highest seasonal average for males was 14.34 days in 1926, and for females 12.81 days in 1924. The average length of life of the males exceeded that of the females six years out of the seven, and during the entire period was 1.06 days longer.

Table 8.—The Length of Life of Male and Female Moths of the First and Second Broods, Grand Junction, Colo.

Year	Sex	Average (Days)	Maximum (Days)	Minimum (Days)
1915	Male	11.86	41	1
	Female	12.68	35	1
1916	Male	13.12	38	1
	Female	12.20	26	1
1922	Male	10.86	35	1
	Female	9.52	33	1
1923	Male	11.57	36	1
	Female	9.39	29	2
1924	Male	13.88	34	1
	Female	12.81	25	1
1925	Male	11.78	47	1
	Female	10.58	45	1
1926	Male	14.34	29	1
	Female	12.75	25	2

Table 9.—The Life Cycle of the First Generation of Codling Moth, Grand Junction, Colorado, 1915 and 1916

Year and Feeding Method	No. of Individuals	Incubation Days	Larval Feeding Period (Days)			Cocooning Period (Days)			Pupal Period (Days)			Life Cycle (Days)		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
1915—Stock jar feeding.....	221	9.91	20.75	32	14	6.99	28	2	11.64	31	6	49.30	72	38
Bagged-fruit feeding.....	109	10.55	22.18	32	15	5.40	22	1	11.03	19	8	49.18	74	36
1916—Stock-jar feeding.....	550	7.67	19.33	34	14	5.61	30	2	12.26	19	6	44.89	77	36
Bagged-fruit feeding.....	188	8.56	20.45	27	17	5.26	19	2	11.86	15	8	46.37	66	38

Table 10.—Life Cycle of the Second Generation of Codling Moth, Grand Junction, Colorado, 1915 and 1916

Year and Feeding Method	No. of Individuals	Incubation Days	Larval Feeding Period (Days)			Cocooning Period (Days)			Pupal Period (Days)			Life Cycle (Days)		
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
1915—Stock-jar feeding.....	16	6.12	20.49	28	16	8.56	16	4	15.62	31	11	50.81	69	40
1916—Stock-jar feeding.....	161	6.01	18.08	25	14	4.78	14	2	13.52	16	11	42.40	54	35

Life Cycle of the First Generation

While accurate information can be secured on the seasonal development by carrying several individuals in a single cage and treating each stage of development largely as a unit without regard to its ancestry, this does not give the most accurate life-cycle data. This can be secured only by having accurate data on individuals through all the stages. Such data were secured in 1915 and 1916, a summary of which is given in Table 9.

The larvæ of some of the material were fed in apples in jars, and the remainder in bagged fruit on the tree. In the table they are listed under the "stock-jar" and "bagged-fruit" feeding methods. To get the complete life cycle, that is, the time from the egg of one generation to the egg of the next, 2.07 days should be added to the length of the cycle for 1915, and 2.21 days to that of 1916. This is the average time that elapsed from the emergence of moths to the deposition of eggs. This would make the average complete life cycle for 1915, stock-jar method, 51.37 days, and bagged-fruit method 51.25 days. For 1916 the complete life cycle is, with the stock-jar method, 47.10 days, and with the bagged-fruit feeding, 48.58 days. The life cycle by the stock-jar method in 1915 was 4.41 days longer than in 1916. It is interesting to note that the maximum cycle is usually about double that of the minimum. The minimum is probably of most importance, as it indicates the rapidity with which the more precocious individuals may go through a generation. It is undoubtedly these that give us the partial third brood. The minimum cycle each year was 36 days, which makes a complete cycle of a fraction of a day over 38 days.

THE SECOND AND THIRD GENERATIONS

Eggs of the Second and Third Broods

As explained before, during most years no attempt was made to separate the second and third broods, and from the standpoint of information for control, little would be gained by so doing. However, in 1915 and 1916, August 19 was selected as an arbitrary date for the emergence of the last first-brood moths, hence the graphs and tables of the egg deposition for those years show only the second brood records. In 1926, the laboratory was closed August 22, so the records are not complete for that season.

Time of Deposition.—The daily records of the deposition of second and third-brood eggs are shown graphically in Plate 3. The dates of the first and last deposition, the period of maximum deposition, and the length of the period of deposition are given in Table 11.

It will be noted that during four of the years, deposition began during June, in 1926 as early as June 24. The latest date of deposition was October 6, 1925. The period of maximum deposition is important from the standpoint of control. It will be noted that it varies in length and time of appearance with the different seasons. During four of the years it began from the second to the seventh of July. In 1925 and 1926 it

began June 28 and 27, respectively, while in 1915 it did not begin until July 14. There is usually a heavy deposition throughout the months of July and August. In 1924 many eggs were deposited early in September. The full period of second and third-brood egg deposition is represented in the years 1922 to 1925, inclusive. This ranges in length from 84 days in 1923, to 102 days in 1925.

Table 11.—The Time of Deposition of the Second and Third-brood Eggs, Grand Junction, Colo.

Year	First Egg	Last Egg	Period of Egg Deposition (Days)	Maximum Egg Deposition	Total Eggs
1915	July 11	Sept. 15	66	July 14-Aug. 31	38,485
1916	July 3	Aug. 31	59	July 7-Aug. 22	46,410
1922	June 30	Sept. 27	89	July 2-Aug. 29	144,980
1923	June 30	Sept. 22	84	July 4-Aug. 30	106,334
1924	July 1	Sept. 18	79	July 3-Sept. 7	192,466
1925	June 26	Oct. 6	102	June 28-Aug. 6	110,254
1926	June 24	Aug. 22	59	June 27-Aug. 22	73,095

Total, 712,024

It has been shown that there is an overlapping of the deposition of the first and second-brood eggs, and again of the second and third-brood eggs, thus making eggs present at all times throughout the season. In this connection it is worthy to note that the time from the first eggs in the spring to the last ones in the fall ranged from 125 days in 1924, to 155 days, or over 5 months, in 1925, and over a considerable portion of this time they are appearing in large numbers. In 1924, which was a disastrous year in control work, eggs were deposited in large numbers over a period of 123 days.

Incubation Period.—Table 12 gives the average, maximum and minimum incubation periods of the second and third-brood eggs. The average varied from 5.46 days in 1922, to 7.38 days in 1925. This is a considerably lower average than for the first brood as shown in Table 5, except for the year 1922, when the difference is only a fraction of a day. The maximums are of little importance, as they usually represent eggs appearing during cool weather of the fall. However, they are lower than the maximums of the first brood. The minimum periods vary from 4 to 6 days for the different years, which is about the same as for the first brood.

Table 12.—The Incubation Period of Second and Third-brood Eggs, Grand Junction, Colorado

Year	Average (Days)	Maximum (Days)	Minimum (Days)
1915	7.22	11	6
1916	6.93	10	6
1922	5.46	10	5
1923	6.73	13	5
1924	6.69	11	5
1925	7.38	10	4
1926	6.93	9	5

Larvæ of the Second and Third Broods

Time of Hatching.—Table 13 gives the dates of the first and last hatchings of these larvæ and the length of the hatching period.

During six of the years, hatching began during the early days of July. In 1925 and 1926 it was July 4. The latest season was 1915, when hatching began July 19. The dates of last hatching are not the very latest for the seasons, but they represent the last of the hatching in any considerable numbers. Incubation records were not taken on the last eggs deposited. This will shorten the length of the actual hatching period by several days. During most years hatching occurred well into September. The hatching throughout the seasons is shown graphically in Plate 3.

Table 13.—The Time of the Hatching and the Length of the Hatching Period of Second and Third-brood Larvæ, Grand Junction, Colo.

Year	First Hatching	Last Hatching	Length of Hatching Period in Days
1915.....	July 19	Sept. 24	68
1916.....	July 9	Sept. 8	62
1922.....	July 7	Sept. 18	74
1923.....	July 6	Sept. 24	71
1924.....	July 7	Sept. 18	74
1925.....	July 4	Sept. 11	70
1926.....	July 4	Aug. 7*	..

*Work discontinued.

Length of Feeding Period.—The length of the feeding period was determined only during 1915 and 1916. During the first year 1,939 larvæ had an average feeding period of 28.69 days, maximum 67 days, and minimum 15 days. In 1916, 2,569 larvæ fed on the average 28.61 days, with a maximum of 70 days and minimum 14 days. Those entering the fruit during the warmer weather had the shorter feeding period.

Time of Maturity.—The first of the second-brood larvæ were mature and left the fruit on August 5, 1915, and on July 23, 1916. In the insectary, few larvæ entering the fruit after the middle of September reached maturity.

Pupæ of the Second Brood

We have considered the eggs and larvæ of the second and third broods together, as there is such an overlapping in their appearance that it is difficult to separate them, but since only second-brood larvæ transform to pupæ and moths during the season of their development, there will be no third-brood pupæ and moths.

Length of the Cocooning Period.—There is a record on the cocooning period of 20 individuals in 1915. This shows an average of 9.35 days, maximum 31 days, and minimum 3 days. In 1916, 171 individuals had an average cocooning period of 4.80 days, maximum 14 days, and minimum 2 days.

Time of Pupation.—In 1915, pupation began August 12, and continued until October 2, while in 1916 it continued from July 27 until August 23, with the maximum number pupating August 1.

Length of the Pupal Stage.—In 1915, the summary of the length of the pupal stage was, average 15.62 days, maximum 31 days, and minimum 11 days. In 1916, with favorable climatic conditions, the average was 13.51 days, maximum 16 days, and minimum 11 days.

Moths of the Second Brood

Time of Emergence.—During 1915 second-brood moths emerged from August 23 to October 14, a period of more than 1½ months. In 1916 the first second-brood moths emerged August 7, and the last September 6, with the greatest emergence occurring between August 14 and 21. It is interesting to note that the first brood moths continued to emerge until August 19, thus causing an overlapping of the emergence of first and second-brood moths from August 7 to August 19.

Deposition of Second-Brood Moths.—Eighty-six female moths deposited a total of 3,920 eggs, or an average of 45.58 per female.

Life Cycle of the Second Generation

In Table 10 are given the summarized data showing the average, maximum and minimum life cycles of second-brood individuals carried in the insectary by the stock-jar feeding method in 1915 and 1916. The average cycle in 1915 was 50.81 days, and in 1916, 42.40 days or 8.41 days less. To get the complete life cycle, 3 days should be added for the time from emergence of moths until oviposition. The minimum cycle for 1915 was 40 days, and for 1916 35 days.

THE THIRD GENERATION

As explained earlier, the individuals of the third generation pass through only two stages of development, egg and larval. All the third-brood larvæ become over-wintering larvæ, along with the non-transforming first and second-brood larvæ.

Eggs of the Third Brood

Time of Deposition.—Third-brood eggs were deposited in 1916 from August 12 to September 21. The largest number deposited any one day was on August 27.

Hatching of the Eggs.—The average incubation period of the eggs was 7.77 days. Hatching began August 20 and continued until September 21. Larvæ were hatching in the greatest numbers on September 4.

Larvae of the Third Brood

Feeding of the Larvae.—Larvæ were entering fruit freely from August 20 until September 21. None of the larvæ entering the fruit after September 11 reached maturity. The length of the feeding period of 133

larvæ in 1916 was, average 37.55 days, maximum 68 days, and minimum 20 days. The third-brood larvæ are what are commonly called the "September worms" by the growers. During some seasons they are responsible for a great amount of injury. This was especially true during 1924.

PERCENTAGE OF INDIVIDUALS PASSING THROUGH SECOND AND THIRD GENERATIONS

It has been pointed out that while many individuals transform to form a third generation, others pass through only one and still others only two generations. The percentage of each brood of larvæ transforming apparently depends, to a considerable extent, upon climatic conditions, especially the temperature. Yet it is difficult to explain why many first-brood larvæ fail to transform, while others form two later generations. The percentage of first-brood larvæ transforming in 1916 was 74.15, and of the second brood 6.71. Of 106 second-brood larvæ reared from the earliest moths, 27 or a little better than 25 percent transformed into third-generation moths.

RELATION OF LIFE HISTORY TO CONTROL WORK

It is hardly necessary to discuss the importance of a thorough knowledge of the life history of the codling moth for guidance in all control work. All operations must of necessity be based directly upon it.

The object of the foregoing discussion on the life history and habits of this insect has been to present the most essential facts needed by each grower. The timing of the sprays according to the hatching of the different broods of larvæ is discussed under the heading of spray schedule. The great seasonal differences that occur in the appearance of the insect in its different stages emphasizes the importance of close observations each season. If the individual grower is not in position to make such observations, for the proper organization of the work, they should be made by some trained person working for the community. The reliance placed upon the spray dates, and other information given the growers during the course of these studies, is proof that such information is needed and valuable.

Control

Spraying with Arsenicals

Spraying with arsenical preparations to poison the newly-hatched larvæ before they make entrance into the fruit has proven the most effective control method. The poisoning is done principally as the small worms attempt to eat into the fruit, but some are poisoned as they eat of the leaves during the comparatively short time they are crawling about before entering the fruit. The effectiveness, therefore, depends largely upon having the poison in killing quantities upon all parts of the fruit at the times larvæ may be entering.

Materials to Use.—The principal arsenical spraying materials are arsenate of lead, arsenate of calcium or lime, arsenate of magnesium,

arsenite of zinc, and paris green. All of these have, at different times, been tested with the result that the arsenate of lead has proven by far the most effective and the least likely to injure the fruit or foliage. It has the objection of being somewhat slow in killing, thus permitting many larvæ to blemish fruits by producing shallow injuries or "stings" before they are killed.

Arsenate of lead is prepared in both a paste and powdered form. The paste formerly was the more generally used, but of late years the powder has almost completely replaced it. The powder has many advantages over the paste that makes its growth in popularity rapid.

Method of Application and Strength of Material to Use.—

Application of the material in the form of dust has been attempted with almost complete failure. While some protection has been secured with both, the arsenate of lead and arsenate of calcium, it has not been sufficient to make this method an effective means of control. It cannot be recommended under the climatic conditions and the degree of infestation that exist in the Grand Valley.

Application in the liquid carrier has been much more effective. Two pounds of the powder to 100 gallons of water has been the most generally used strength, although there has been a growing tendency to increase this to 2½ to 3 pounds to 100 gallons, or even higher. Results have not indicated that the higher strengths are more efficient, so we would not recommend more than 3 pounds to the 100 gallons as a maximum.

Spreaders.—The waxy coating of fruit prevents the mixture of water and arsenate of lead from spreading uniformly, with the result that the arsenate is left more or less in blotches. Various materials have been used in an effort to overcome this. The most effective of those that we have tried are fish oil soap, linseed oil soap, and calcium caseinate. Resin is sometimes added to the fish oil soap to increase the adhesiveness of the arsenate of lead, but this seems to be unnecessary. The fish oil soap is usually used at the rate of from 3 to 6 pounds to 200 gallons of spray solution. We have secured what we felt was the most ideal spreading effect from linseed oil soap. Three pounds of the jelly form of this seems sufficient. The casein which is taken from milk and the different preparations made from this casein, most of which are calcium caseinate, are probably the most desirable spreaders to use considering all points. They come prepared in a powdered form that dissolves readily, and are more reasonable in cost, since from 1 to 1½ pounds are sufficient for 200 gallons of spray.

The real value of spreaders in codling moth control is debatable. In our tests we have failed to get results to prove that they are beneficial and some of the growers that are the most successful in their control work do not use them; however, many believe that they are worth the extra expense.

Some manufacturers of arsenate of lead incorporate what they term

spreaders in their finished product. In some cases these are only "suspension agents" or "deflocculators" that cause the arsenate to stay in suspension better, but do not cause the liquid to spread over the fruit any better. In other cases, casein is incorporated, which forms a calcium caseinate spreader when the recommended amount of lime is added at spraying time.

The Spray Schedule.—The necessary number of applications of spray will depend somewhat upon such factors as degree of infestation, seasonal temperatures, varieties, size of fruit, rate of growth of fruit, size of trees, and type of pruning. No one schedule will exactly meet the demands of all the growers; however, the infestation and conditions are serious enough in all orchards of the valley to demand a schedule that is more extensive and exacting than will give satisfactory results in many fruit-growing sections. The difficulty of the problem has led many to increase the number of applications to a point beyond business expediency, and from all observations little has been gained in the way of better control. The object should be to make applications at the most opportune times, and to hold the expense down as much as possible, which at the best is very high in proportion to the orchard returns of the past seasons. It is questionable whether any orchardist should make more than 7 or 8 applications at the maximum, but some have applied 9, 10, and even more. Results taken from definite fruit counts made in the orchards do not show that the extra sprays above the 7 and 8 sprays have been justified. We would recommend that the 7- and 8-spray schedule be used with the additional efforts being directed toward the other methods of control which are discussed later.

Many of the newly-hatched larvæ of all broods find entrance into the fruit through the blossom end. The percentage entering at this point varies somewhat with the season of the year, the variety of fruit, and other factors, but counts have shown that it varies from 25 to 80 percent. To get poison into the calyx basin to poison these larvæ, a spray must be applied just after the blossoms fall and before the calyx lobes of the small fruits curl upward and close the basin against the entrance of the spray liquid. There are from 7 to 10 days just after the blossoms fall when efficient calyx spraying can be done. It is well for the grower to be prepared to complete this work in one week. It may be begun when the blossoms are 95 percent off, but on account of the danger to bees the trees should never be sprayed while blossoms that attract bees are present. The calyx spray is, therefore, the first codling moth spray and a very important one. The object in mind while applying this should be to strike all small fruits directly in the blossom end with the spray. This can be done only by spraying from several directions. A great many blossoms will be found to point upward, hence the importance of a tower from which to work. The calyx is probably the most effective single spray, but does not give

any protection against the larvæ that enter through the sides of the fruit. These must be poisoned by the cover sprays.

It will be seen from Plate 3 that, while there are larvæ hatching and entering fruit at all times during the season after the first ones appear, there are two critical periods when the numbers are much greater. It is important that the growers know the time of hatching of each brood of larvæ and have the fruit well protected during these two periods of maximum hatch, but the first one is of greatest importance, as all that are missed at this time are increased several times in the second and third broods.

It is almost impossible to overcome by late sprays inefficiencies of those applied against the first brood. Early in the season the fruits are having their highest percentage increase in area and will, therefore, outgrow a cover of spray in a short period. At times during the hatching of the first-brood larvæ, the surface area of the fruits may be doubled in from 7 to 10 days, while later it may take as much as 25 or 30 days for this to occur. The best results are secured by concentration of effort on the first brood. Even though the second and third-brood larvæ are appearing over a longer period than are the first, at least one-half of the cover sprays should be applied against the first. With the 7-spray schedule, three of the six cover sprays are used on the first brood, and three on the second and third broods, while with the 8-spray schedule, four are applied against the first brood and three against the later ones. The first cover spray should be applied as soon as newly-hatched larvæ appear. This will usually be about 12 to 16 days after the blossoms fall from the standard varieties of apples. This is shown, for the years during which work has been done in the valley, as the beginning of the hatching curve illustrated in Plate 3. If three cover sprays are used on the first brood, the second should follow in 10 or 12 days and the third in another 14 days. With four cover sprays against the first brood, the second may follow in 10 days, the third in another 10 or 12 days, and the fourth in still another 12 days. The 7 and 8-spray schedule each call for three cover sprays on the second and third broods combined. In the absence of careful observations on the appearance of the second brood of larvæ, it can fairly accurately be considered as starting 6 weeks after the first, or 8 weeks after the blossoms fall, but if advantage can be taken of expert advice on this, it should by all means be followed, as a study of Plate 3 shows the seasonal variations are great. The first second-brood cover spray should be made when the larvæ begin to appear in numbers, the second one 16 days later, and the third and last one about 18 days later.

It will be noted that the schedules suggested do not conform with those that have been recommended to control the codling moth, and avoid quantities of spray residue that are objectionable. Such schedules are entirely impractical for Grand Valley conditions. It is necessary to take care of the residue problem in other ways.

Equipment for Spraying.—Since spraying for the control of the codling moth is one of the most important pieces of work of the orchardist, the best of equipment should be available. Fortunately there are a number of power spraying outfits that give satisfactory results. The size to be selected will depend somewhat upon the acreage to be sprayed, yet the smaller outfits are likely to be less effective. The triplex pumps that will supply at least two lines of hose with a pressure of from 225 to 300 pounds are about as small units as should be selected for a commercial orchard. Much delay in spraying comes from having an engine of too low horsepower. There should be power enough that the engine will not be overworked.

In all orchards of larger trees all machines should be equipped with a tower so the tops of all trees can be adequately sprayed. Often one operator can work from the top of the spray tank and have elevation enough. A sawhorse placed here will enable one to steady himself when the machine is in motion.

It has been found by examination of fruits from all parts of the tree, and by trapping moths in the upper and lower parts, that the heaviest infestation occurs in the upper half of the tree. This is the part most difficult to spray. The operator on the ground with the spray between him and the tops of the limbs, is often deceived in the quality of the work being done; then, it is impossible to do thorough work in either the calyx or cover sprays working from beneath only.

The nozzles and spray rods are very important factors. Good work can be done with a number of combinations, but it is much easier with some than others. The spray guns have come into favor during late years. However, there has been somewhat of a return to rods and the whirlpool type of nozzles during the last year or two. The spray guns have many points in their favor, but unless they are carefully manipulated, it is questionable whether they do as high quality work as do the nozzles. The spray guns are so made that the type of spray can be changed by the operator. It is possible from one position to spray parts of the tree that are 6 and 8 feet and others that are 15 to 20 feet away, with a spray of about the same character. If the operator will learn just the type of spray for each distance, and then constantly adjust the gun so that this will be maintained, good work will be done. But few operators do this. The fault is more with the operator than with the gun, but unfortunately the gun seems to lead to carelessness. Also many of the older types of machines do not have the capacity to properly handle the guns.

There are two types of nozzles in general use, the bordeau that produces a fan-shaped spray, and the vermorell or whirlpool type that makes a cone-shaped spray. The latter are in more general use, largely on account of the tendency of the former to wear out, especially with dirty water, and to drip and waste much material. At one time many thought the bordeau nozzles were better adapted for making the calyx applications on account

of giving a somewhat more driving spray, but there seems to be no foundation for this belief. The type of spray produced by most whirlpool nozzles can be improved by making a small hole in the center of the nozzle core, in addition to the holes on the sides. This combination gives instead of the hollow cone of spray, a solid cone which is less affected by wind and gives a more uniform coverage over all the area being sprayed.

The length of rod for best results may depend somewhat upon the size of trees and character of spray given by the machine and nozzle. The rods of 10 to 12 feet in length are most too difficult to handle with the machines maintaining the higher pressure.

A combination of rod and nozzles giving excellent service is a light rod about 6 feet long, with 2 whirlpool nozzles on a "Y." Six inches from one end the rod is bent at an angle of about $22\frac{1}{2}$ degrees. Each core in the nozzles contains five holes, one 3-32 of an inch in diameter in the center, and four 5-32 of an inch in diameter equidistant on the sides. Those on the sides are bored in at an angle in order to give the whirlpool effect, and the one straight through the center, to give the solid cone effect. These nozzles will produce a spray that will carry 18 feet with 250 to 300 pounds pressure. This will reach the more distant parts of most any tree. The angle at the end of the rod enables the operator to reach the more inaccessible parts. The balance in the rod is good and makes it less difficult to hold on account of avoiding, to a considerable extent, the "kick-back" so objectionable in many rods with angle nozzles. The nozzles give a fine but penetrating spray. The size of the hole in the disk should be adjusted to the capacity of the machine, and the volume of spray desired.

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 Plate 4. 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.

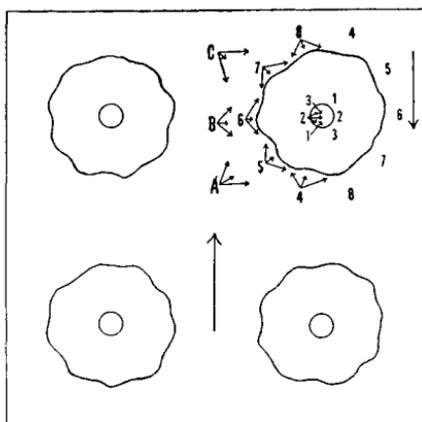


PLATE 4.—Suggesting a system of work in the orchard to develop thoroughness in spraying. The long arrows indicate the lines of movement of the machine. The man on the tower sprays from the positions of A, B and C, and repeats from similar positions when the machine is on the other side of the row. The 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.

Pruning for Better Spraying.—The codling-moth situation is so serious that all orchard operations should be carried out with their relation to the control work in mind. This is especially true of pruning. There are many theories and practices in pruning work that are important, but



Figure 3.—Effective codling moth control is impossible in this unpruned orchard. The trees are also too close together.

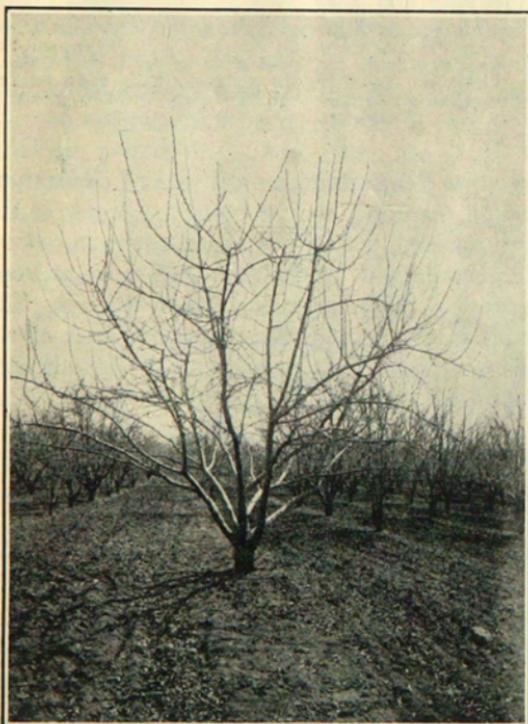


Figure 4.—The tree in the foreground, while not ideal, is fairly well pruned for efficient spraying.

none are so rigid but what they can be varied, if necessary, to make codling-moth control more effective. The grower can well sacrifice some fruiting wood in order to be able to better protect the fruit on the remainder. The problem is not how much fruit but how much good fruit can be grown. Each tree should be so pruned that there are several entrances through which the operator can get to the center of the tree to spray. The limbs should be so spaced that they can be sprayed from different angles and the trees should never be allowed to grow to extreme heights.

CONTROL METHODS TO SUPPLEMENT SPRAYING

Successful control of the codling moth cannot be accomplished under the conditions that exist in the Grand Valley by any one operation. All possible means that are at all practical must be used. While spraying with arsenicals to poison the small larvæ as they enter the fruit has proven the most effective single method, it alone should not be depended on.

Banding the Trees.—One of the first methods ever used for the control of the codling moth was the use of cloth bands to catch the larvæ. It is still worthy of serious consideration. In fact, it probably ranks next to spraying in importance for sections having a heavy infestation, and is advised in any orchard in which the insect cannot be kept well under control with from 3 to 5 sprays. Burlap of at least two thicknesses has proven about the most satisfactory material. The bands should be at least 4 inches wide and long enough to reach once around the tree. They may be made from old sacks or burlap wrapping material, but the ready prepared banding material with sewed edges is more satisfactory. The success of the bands depends largely upon the thoroughness in scraping all rough bark from the tree and care and promptness in handling them. They should be in place by June 5 and be removed each 10 days thereafter until September 1, and all larvæ or pupæ found under them destroyed. All worms that enter the bands after September 1 can be killed at one examination any time before the spring emergence of moths. Bands properly handled will catch from 25 to 40 percent of the larvæ.

Screening of Packing Sheds and Sanitation.—The fruit harvest always concentrates many overwintering worms in and about the packing shed. Wherever it is at all possible such sheds and all storage houses should be screened to prevent the escape of moths in the spring. All picking and storage boxes should be placed in moth-tight houses or be gone over before spring and all larvæ killed. Any rubbish in which worms can hibernate should be burned.

Thinning the Fruit.—Judicious thinning can have two important bearings on codling moth control. First, the fruits that are wormy from first-brood larvæ can be removed and destroyed, thus materially reducing the second and third broods that would develop, and which are even more difficult to control than the first. Second, all clusters of fruit can be broken, thus destroying a favored place of entrance and making it possible to more thoroughly spray the remaining fruit. The thinning, to be most effective, should be done before many first-brood larvæ are maturing. During most years it should be completed by the middle or latter part of June at the latest.

Removal of Light Crops.—Certain varieties of apples and pears have a tendency toward alternate years of light crops and occasionally spring frosts may reduce the crop below normal. In such cases, where the crop is much below normal, it is often best to remove the fruit instead of

trying to keep it free from worms. With a heavy infestation concentrated upon a limited number of fruits, little of the crop can be saved, and the expense is usually greater than the cost of removal. The removal of the fruit will reduce the infestation for the next season, even if it is done only on individual trees. If this is not done, the light crop may be destroyed before the season is over and much migration occur to sections of the orchard having more fruit. It is seldom worth while to undertake to protect a crop that is as much as 50 percent below normal.

Elimination of Undesirable Varieties and Orchards.—

The dairyman has learned that his success may depend upon the elimination of the undesirable individuals of his herd, but many orchardists have failed to apply this same principle to the orchard. The feeling against the destruction of a tree has made the condition worse.

All odd trees that complicate the control work should be either top worked to standard varieties, or destroyed. The same principle must be applied to orchards or parts of orchards that for any reason will not justify the heavy expense of the many phases of control.

Codling-Moth Traps.—The suggestions in regard to the codling-moth traps are made from the results of the work done by the junior author.

The experiments to date indicate that there are possibilities in this field of investigation. It is hoped that it can be carried further and that some growers can trap a part of their orchards.

In 1924, 60 traps averaged 64.11 moths per trap; 34 traps in 1925 averaged 107.5 moths, and 5 traps in 1926 averaged 114 moths. Individual traps have caught as high as 237 moths in a season.

The type of container giving the best results is the common, wide, open-mouth quart glass fruit jar. The tin-can containers rust out too soon. The glass jars are filled and hung in the upper third of the trees where most of the moths taken are caught. This was illustrated by a test made on 5 trees. Each tree contained a trap in the lower part, and one in the upper part. During a period of 27 days, when the moths were numerous, the upper traps caught 13.5 times as many moths as the lower traps.

A number of solutions have been used, some containing certain aromatic chemicals, others the fermented apple juice. The fermented apple juice gave the best results. This juice is prepared by boiling approximately one box of apples cut in quarters in $4\frac{1}{2}$ gallons of water for about an hour. The resulting liquid is drawn off and allowed to ferment. In some cases sugar and yeast cake or rotten apples have been added, but this does not seem to improve the attractiveness of the solution. A quart glass jar filled to within a half inch of the top with this fermenting solution is hung in the trees. This solution diluted with 25, 50 or even 75 percent water gives as good results as when no dilution is made.

Solutions containing certain aromatic chemicals have been tested, and while the work has not gone far enough to make any definite recommendations, a few do show some promise. The most outstanding ones are isobutyl phenyl acetate, bromo-styrol, safrol, diphenyl oxide, benzyl benzoate, citronellal, phenyl, ethyl alcohol, citral, ethyl benzoate, isobutyl acetate, diethyl phthalate, geraniol, methyl cinnamate, amyl salicylate and cenanthic ether.

One cubic centimeter of the aromatic was used to one quart of water sweetened with a little sugar. A little glycerine was added to some of the aromatic solutions, but just as good results were obtained where no glycerine was added.

Many growers use vinegar solutions, and while they are not as attractive as the fermented apple juice, the 10 to 25 percent mixture of ordinary vinegar with water is very good. One grower, using a solution of 25 percent vinegar and 75 percent water in 900 containers caught approximately 18,000 spring-brood moths in 1922.

The jars are suspended in the trees by means of a hooked or looped wire. They can be placed by means of a hook on a long handle. The liquid in the jars will last from 10 to 30 days, depending upon weather conditions.

More females than males are caught in the traps. Because of this fact, the suggestion has been made that perhaps most of the moths emerging in the field are females. Our data show that, of all the moths emerging under laboratory conditions, there are about the same number of males as females. Presumably the same condition exists in the field. The larger number of females caught might be due to their being more active in feeding.

The question comes up rather often as to the number of eggs deposited before the moths are trapped. A definite answer to this cannot be given, but an examination of the trapped female moths shows that, in the ma-

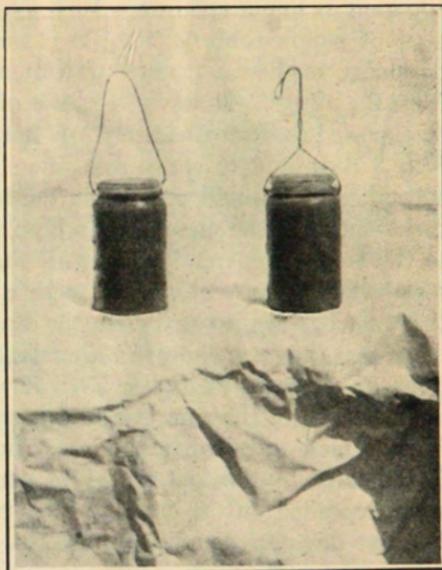


Figure 5.—The glass quart fruit jars have been found efficient codling moth traps when baited with fermenting apple juice. They can be hung in the tree by means of wire attached as shown.

majority of cases they are usually well filled with eggs. This indicates that the moths usually get in the traps before depositing many of their eggs.

Ovicides.—Most of the effort in spraying has been directed toward poisoning the larvæ. This method, while quite effective, is not entirely so. It is sufficient for satisfactory control in many sections. Under conditions of light infestation, the degree of failure of this method is not so apparent as under conditions such as exist in the Grand Valley. Here the need of supplementary methods is more urgent, especially since with the poisoning method a certain amount of blemished fruit is bound to occur from the stings. However, the use of materials to destroy the egg cannot be expected to control entirely. It has been shown that eggs hatch in from 5 to 8 days and to spray that often would be out of the question. Any substance that would remain on the leaves and fruit to kill eggs that are deposited after the material has been applied is very likely to be injurious to the tree. Apparently about all that can be expected of ovicides is to supplement the arsenicals. If a safe and effective material can be found that can be incorporated with the standard spray for certain applications when the eggs are the most abundant, it will have a place under conditions of severe infestation. Even if a single application could be applied against each of the first two broods of eggs when they are at their height, it could materially reduce the infestation. The possibility of such a method is indicated by the fact that 11.3 percent of the first brood eggs of 1924 were deposited on the one day of June 6 and 39.4 percent were deposited in a five-day period ending June 6.

Of a large series of materials tested, the oil sprays have been the most effective, but they have had the objection mentioned above of being more or less injurious to the tree. Some of the "summer oil emulsions," made from highly refined oils have been the least objectionable, but as yet all of these should be considered only in the experimental stage for codling moth control, and if they are used it should be in only a limited way. The injury may be manifested in several ways and is not always apparent immediately after application. The high temperatures reached at times in the Grand Valley make such materials much more likely to injure than in many other sections. At least minor injury has been apparent in all orchards where the oil preparations have been used as summer sprays.

FACTORS AFFECTING CODLING MOTH CONTROL

Tenantry System.—For a number of reasons there are more than the usual number of small orchard tracts in the valley that are owned by non-resident people and must be leased. This has been a real drawback to the most effective codling moth control. Many of these places are for rent because the owners found them unprofitable and it is unreasonable to expect the tenants to make a success in handling them. The successful growers are those who plan and work years ahead and even know the

individual trees in their orchards as a stockman would know the individual animals in his herd. The tenant is usually working on a yearly basis and cannot even if he is inclined to do so, do the necessary work to keep the orchard in prime condition. Many tenants also make the practice of watching for the orchards that they know will be in prime condition for a very heavy crop and then lease these and take the crop off with the least possible expense, leaving the orchards to be cared for another year either by the owners or other renters. It usually takes a series of years of very careful and thorough work to get the best results in the control of the codling moth. If orchards are to be rented they should be rented on the basis whereby the tenant can afford to do the necessary cleanup work and be required by the lease to do so, and get the profits that will result from his work at the end of the second or third year. If the nonproducing land owner cannot or will not make such arrangements, he cannot expect to find reliable renters, and an orchard under these conditions cannot be made profitable.

Lack of Machines.—The Grand Valley with its heavy spraying program probably has a larger equipment of spray machinery than most fruit-growing sections, but there is still need for more up-to-date machinery. Too many orchardists have been depending upon their neighbors for their spraying work. While it is realized that the small owners cannot all afford to have machines, there should be enough available to spray the entire acreage of orchards within five to eight days. Under the present conditions this cannot always be done. This means that many have not had their spray applications made at a time that will give them the most protection. It is doubtful if one ordinary machine can take care of more than 15 to 20 acres of bearing orchard, so any orchardist that engages a machine and does not have a very definite understanding as to the amount of work this machine is to do and just when he can secure it, is taking a great chance upon his crop. Each individual should make every effort possible to have a complete equipment of his own. If this is not possible, there is no reason why a limited number of small growers could not have their own equipment and confine its work to their own acreage.

System of Charging for Custom Spraying.—The system of charging for the custom spraying that is in vogue at the present time has been a great drawback to the most effective work. Spraying for a stated amount per 200-gallon tank of material has had a tendency to lead to careless work rather than to the most thorough work that is necessary. It naturally leads to the tendency to spray out as large a number of tanks as possible. This cannot help but lead to the breaking down of the more sound spraying practices. It is only human nature that anyone will wish to make all the money possible out his work and the abuse has grown to a considerable extent upon the entire section little by little. The custom sprayer who does good work is entitled to good wages and considerable

for the wear and tear on his machinery, but in his ambition to spray out large numbers of tanks he should not forget the interests of his employer. It is doubtful if any ordinary equipment can satisfactorily put out more than ten 200-gallon tanks of spray in one day, yet it is not uncommon for many machines that do custom work to put out many more than this. This usually means that much material has been wasted and poor work has been done. A part of this difficulty could be overcome if all of those that must depend upon hired machines would hire them only by the hour and pay for their actual running time. This could well be more per hour than is being paid for machines at the present time, and still the employer be the gainer. Many of the machines that are for hire, even though they may be in good mechanical condition, are equipped with worn and inefficient nozzles and spray guns. The one hiring such machines is too willing to accept the outfit as it is brought to him and with these conditions in the ordinary rush of the season's work, the best work cannot be expected. Even if there is only a small acreage concerned the owner certainly could afford to have his own equipment of rods and nozzles that would be used for his own orchard only and depend upon the custom sprayer for only the power. In this way he could get his spray adjusted so thorough work could be done and when he started on his next application the same character of spray would be available and more uniform work would be possible.

NATURAL ENEMIES OF THE CODLING MOTH

Very few parasitic or predacious insects have been found feeding on the codling moth. Only one has shown any indications of being a factor in the control. This is the small egg parasite, *Trichogramma minutum* Riley. In one case as high as 80 percent of the second-brood eggs were found to be destroyed. Eggs parasitized by it can usually be found quite abundant late in the season, but it is seldom found destroying the first-brood eggs. This is probably due to the fact that the winter greatly reduces the numbers. The high parasitism is usually found in unsprayed orchards, indicating that the spraying may have an effect upon the parasite. This little parasite might be made an important factor for control if it could be reared or wintered in large numbers, and released upon the first-brood eggs. The adults puncture the codling-moth eggs and deposit their own eggs within. There are usually two and sometimes three of the parasite eggs deposited in each codling moth egg. The parasitism turns the eggs black, making them very easily distinguished.

CODLING MOTH AND THE PEAR

For the most part the apple has been the fruit in mind in making the recommendations of control, but they apply to the pear as well. The pear is somewhat easier to protect than the apple, but not enough so to call for a change in the recommendations. Since the calyces of the pear do not close as quickly or as completely as those of the apple, some have

thought that the calyx spray could be omitted, but in all cases where this has been tried, disaster has resulted. There is a somewhat longer time in which the calyx spray can be effectively applied, but it should be considered essential. The schedules for the cover sprays as recommended for apples should be followed even though the last application may come when some varieties are almost ready to pick. As with the apples, special attention should be given to the efforts against the first brood, and the various supplementary methods of control should be made use of, but at times in spite of all this, much late loss may occur unless the late spraying is thoroughly done. It will be recalled that in 1924 a considerable percentage of the Bartlett crop was lost by late worms, even after the first picking had been made.

CODLING MOTH AND THE SOFT FRUITS

The codling moth has been considered essentially a pest of the apple and pear, but its tendency to feed upon other fruits is being watched with alarm. Probably the greatest injury has occurred on the plums and prunes. These fruits are not grown extensively in the valley, so we have had opportunity to observe the injury only as it occurs on limited plantings in connection with the apples and pears. Under these conditions the loss may be almost total. Burbank plums have, by actual count, been found to be over 80 percent infested, and one orchardist stated this last fall that for some two or three seasons he had not attempted to use fruit from some five or six prune trees growing near his packing shed. At the time, uninfested fruits were difficult to find on these trees, although a heavy crop was present. The blue Damson is the only variety of plum growing in the section that we have not observed it in. In 1925, the fruit on two apricot trees growing in an orchard on First Fruit Ridge was so badly infested that little of it was used. Infested apricots are common in most sections of the valley. It is occasionally found in the peach, but this is always where trees are growing near apples and pears. It has been bred from several varieties of sweet and semisweet cherries. On one occasion, 16 wormy fruits were taken from a 16-pound box of Royal Ann cherries. This last season, it was reported as infesting the grape, but the report could not be verified. The general adaptation of the insect to the soft fruits would be a calamity.



Summary

The codling-moth infestation in the Grand Valley is unusually heavy. The fruit in unsprayed orchards is usually a complete loss. It has been possible to count as many as 100 eggs on fruit and leaves in one minute.

Studies on the life history and control were carried on each season from 1914 to 1926, inclusive, with the exception of 1920. There are two complete generations and a partial third generation of the codling moth in the Grand Valley in a year. The spring-brood of moths began to emerge April 24, 1925, while in 1922, emergence did not begin until May 13. The period of spring-brood emergence varied in length from 39 days to 49 days. The daily moth emergence for seven seasons is shown in Plate 2.

Of 5,525 spring-brood moths examined, 45.4 percent were males, and 54.6 percent females.

Egg deposition may begin within one day after the moths emerge, but during the cooler weather, it may not begin for as long as 10 to 17 days. The average number of eggs for all spring-brood females was 23.12 in breeding cages. In 1924, the average was 46.07 eggs per female. The maximum egg deposition occurred on the eighth day during the life of the moth. Eggs were deposited as late as the 29th day.

During five of seven seasons the average length of life of the female spring-brood moths slightly exceeded that of the males. The highest seasonal average length of life for males was 18.41 days in 1924, and for females 17.24 days in 1924. The maximum length of life was 39 days.

The daily first-brood egg deposition is shown in Plate 3. The earliest date for deposition to occur was April 29, 1926, and the latest date was July 9, 1922. The average length of the period of deposition was 51.5 days, and maximum, 56 days. The period of maximum deposition usually occurs during the latter part of May and the fore part of June.

The seasonal average of the first-brood egg incubation period varied from 5.82 days in 1922 to 10.73 days in 1925. The earliest date for hatching of first-brood larvæ was May 15, 1926, while in 1916 they did not begin to hatch until June 1. First brood hatching continued into July each season, except 1925 and 1926. It may continue until second-brood hatching begins. In 1915 there was a hatching period of 52 days.

The seasonal averages of first-brood larval feeding periods varied from 20.19 days to 22.73 days. The minimum feeding period was 12 days, and maximum 42 days.

Mature larvæ were collected under bands as early as June 5 in 1914 and 1922.

First-brood larvæ may spin cocoons and transform to adults in eight and nine days, but it usually takes from 10 to 14 days. To prevent the escape of moths when bands are used, they should be removed every tenth day.

Plate 2 shows graphically the daily emergence of first and second-brood moths. The broods were not separated. The earliest date of first brood emergence was June 21 in 1925 and 1926. In 1915 the first emergence occurred July 9. First and second brood moths emerged over a period of 89 days in 1924. The average duration of emergence was 71 days. The latest date of emergence was September 26, 1924. The period of maximum emergence occurred usually during the latter part of July and fore part of August.

Of 18,337 first and second brood moths handled, 48.3 percent were males and 51.7 percent females. Many first and second brood moths begin egg laying within one day after emergence. The average duration of egg laying was 14.54 days, maximum 23 days. The number of eggs per female was about three times as many as with the spring brood. The lowest seasonal average was 43.98 eggs per female in 1916, and the highest was 130.04 in 1924. Egg production by individuals was found to vary from nothing to 316. The dissection of mature females showed a normal development of from 300 to 340 eggs per female. The maximum deposition during the life of the moths occurred on the third day. A few eggs were deposited as late as the 25th day.

The average length of life of the males slightly exceeded that of the females during six of the seven years. The highest seasonal average for males was 14.34 days in 1926, and for females 12.81 days in 1924.

The first generation complete life cycle in 1915 was, average 51.37 days, minimum 36 days. In 1916 the average was 47.10 days, and minimum 36 days.

The daily egg deposition is shown in Plate 3. The second and third broods were not separated. The earliest date of second brood egg deposition was June 24, 1926. Egg laying is heavy during July and August, and may continue into September. In 1925, second and third-brood deposition occurred over a period of 102 days. There is an overlapping in the appearance of first and second, and again of second and third-brood eggs. In 1925, the entire egg laying period extended over 155 days. The incubation period of second and third-brood eggs varies from 4 to 13 days. The lowest seasonal average was 5.46 days in 1922 and the highest 7.38 days in 1925.

The hatching of second-brood larvæ may begin as early as July 4 and continue to September 24. The feeding period of second-brood larvæ varied in length from 14 days to 70 days, with an average of about 28 days.

Pupation of second-brood larvæ began August 12 in 1915, and July 27 in 1916. The combined cocooning and pupal period is somewhat longer than for the first brood.

Second-brood moth emergence began as early as August 7, and continued until October 14. There is an overlapping in the emergence of first and second-brood moths.

The average seasonal second generation life cycle varied from 42.4 days to 50.81 days, and the minimum cycles from 35 to 40 days.

Third-brood egg deposition begins about the middle of August. The larvæ from these are what are called "September worms," and may be responsible for much late injury.

Fully 75 percent of the first-brood larvæ transform to form a second generation and probably 8 to 10 percent of the second give rise to a third generation. The third generation individuals pass through only the egg and larval stages.

Spraying with arsenate of lead is the most effective single means of control. Dusting gives little control.

Experimental tests and the experience of growers do not prove conclusively the value of spreaders. The most promising spreaders are fish oil soap, linseed-oil soap and calcium caseinate. The last is the most convenient and economical.

Seven or eight sprays should be the maximum. Additional efforts give best results when directed toward other means of control. The calyx application is the most effective single application. With the 7-spray schedule, three cover sprays are applied against the first brood, and three against the second and third broods. In the 8-spray schedule, four cover sprays are applied against the first brood.

It is impractical to reduce the spraying to a point where the spray residue will not be objectionable.

Only the best power equipment should be considered. The tops of trees are the most heavily infested and the most difficult to spray. The tower makes it possible to do more thorough work.

Good work can be done with a number of combination of nozzles and rods. The capacity of the machine and the size of the trees are the most important factors in determining the selection of this part of the equipment. Spray guns often lead to careless work.

A definite system of work should be developed for the spraying of each orchard. A system is suggested for orchards with the larger trees.

The pruning should be such as to make thorough spraying possible.

While spraying is the most effective means of control, it is advisable to follow certain other methods. The use of cloth bands is the most effective supplementary method. The trees should be well scraped and the bands be in place by June 5. The bands should be removed and all larvæ and pupæ killed each ten days until September 1, and once after fruit harvest is complete.

Packing sheds and storage cellars should be screened before the spring brood of moths escape.

The removal of all wormy fruit at thinning time is of material value.

Under the conditions that exist in the Grand Valley, it is useless to attempt to protect a light crop of fruit. It is more economical and greatly reduces the infestation to remove the fruit before it becomes infested. The trees of odd varieties and those especially difficult to protect should be removed.

The trapping of the moths by means of baits shows considerable promise and is worthy of trial. Fermenting apple juice has proven the most practical bait. The material is placed in glass quart fruit jars, which are hung in the upper third of the trees.

Of a large number of materials tested as ovicides, the oils have proven the most effective. Their use, however, has been accompanied by injury to the fruit or trees. They should be used very cautiously until more thoroughly demonstrated. The "summer oil emulsions" are the least likely to injure the trees and are worthy of trial on a few trees.

The system of leasing orchards, the lack of spray machines, and the system in vogue of charging for custom spraying have a very direct bearing upon thoroughness in the control work.

It is recommended that each orchardist that hires a machine to do his spraying, secure his own equipment of rods and nozzles.

The codling moth is especially free from natural enemies. The egg parasite, *Trichogramma minutum* Riley, at times destroys many eggs.

The same program of control as recommended for the apple should be used on the pear.

The codling moth shows indications of becoming a pest upon soft fruits. It has, at times, done serious injury to plums, prunes and apricots, and may attack the sweet cherry and peach.

"Don'ts"

1. Don't omit the calyx spray. Put it on when 95 percent of the petals have fallen, and fill every cup.
2. Don't let other orchard practices interfere with your spray schedule.
3. Don't expect good spraying to result from an old and mechanically inefficient spray machine. Keep it in good condition.
4. Don't fail to spray the centers and tops of your trees. There are apples in those places.
5. Don't attempt to time your spray dates by orchard inspection alone. It is very misleading. Get expert advice, if it is available.
6. Don't expect a poorly-pruned tree to be easily sprayed. It may be even impossible to do thorough work.
7. Don't try to see how much spray you can put on in a day, but instead see how well you can apply it, even if the amount be considerably less. Quality, not quantity, is what you want.

8. Don't let careless work lower the efficiency of your spraying. Spraying is the main reliance for control.
9. Don't spray an apple from one side only. Spray from at least two or three sides and cover it.
10. Don't neglect the scraping and banding of your trees as this method very materially reduces the infestation.
11. Don't fail to practice orchard sanitation. It means a lot of extra work, but it is worth it.
12. Don't fail to thin your fruit and destroy the wormy apples. It pays.
13. Don't try to spray a light crop and expect it to be clean. Better destroy the crop and wait until next year when conditions should be better.
14. Don't make up and use certain spray mixtures suggested by others not well informed. They are usually harmful to the trees and fruit.
15. Don't become sold to high-sounding ideas about codling-moth control. Only methods backed by practical and experimental data are safe to follow. The best tests of control methods and practices come under extreme conditions, so it is very likely that practices that have stood the test under the conditions in the Valley are the best for that section.

As a rule people spray only as well as they have to. The thoroughness developed is usually determined by the difficulties encountered. Ask the fellow who has had experience under other conditions, or no experiences at all and has a sure cure for your troubles, if he will take the consequences of his recommendations.