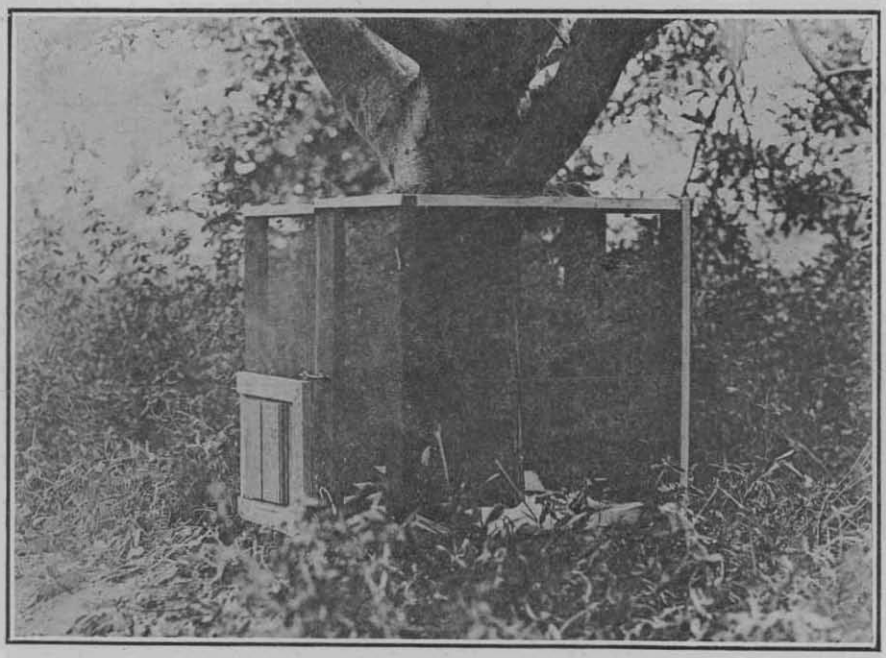
UNIVERSITY OF IDAHO
AGRICULTURAL EXPERIMENT STATION
Department of Horticulture

The Codlin Moth in the Payette Valley



Cage used for observing stages in Life History Study of the Codlin Moth.

BY

L. E. LONGLEY

BULLETIN NO. 124 JUNE 1921

Published by the University of Idaho, Moscow, Idaho.

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THE CODLIN MOTH IN THE PAYETTE VALLEY

L. E. LONGLEY

The study of the codlin moth in the Payette Valley during 1920 was undertaken by the Horticultural Department of the Idaho Agricultural Experiment Station at the request of the fruit growers of the valley. The work was carried on by the station in cooperation with the University of Idaho Extension Division and the Payette County Farm Bureau. The fruit growers of Payette County paid the expenses incurred in prosecuting the studies. Most of the work was in Payette County, but one observation station was located in Washington County on the orchard of Mr. John Moulton, where much valuable data were secured.

During the season of 1919 there was a high percentage of worms in the Payette Valley. Many of the growers decided that this condition was due, largely, to the fact that the cover sprays were not applied at the proper time. Accordingly, they desired more accurate information on the proper dating of the various sprays and requested the Department of Horticulture send a man to Payette for the summer. The author reached Payette on May 2, 1920, and remained until early August. He devoted his entire time during this period, to the study of the codlin moth and related horticultural problems. A week was spent there during picking time, in September, 1920, to check up on the spraying work. Owing to the pressure of other work, it was impossible to devote the entire summer to this investigation.

The study of the life history of the codlin moth was made in order to obtain facts that would aid the fruit grower in better controlling the insect. Observation points were scattered all the way from the Valley View section, three miles east of New Plymouth, down the Payette and Snake valleys, almost to Weiser. The observation points were thus scattered in order to determine whether there is considerable variation in the stages of development of the insect and consequently in the dates of spraying in the various localities.

A summary of the life history of the codlin moth as it has been worked out in other places is introduced here so as to make it easier for the reader to follow the later discussion.

Summary of the Life History of the Codlin Moth in United States. The codlin moth hibernates in the larval or worm stage. As the worms leave the apples in the summer and fall they make their way to the ground. Sometimes they spin a web as they drop to make their descent easier. They spend the winter in cocoons (see Plate I), which are placed sometimes on the trunk of the tree under scales of bark, often as high up as the first crotch of the tree and sometimes more abundantly on the trunk just at or a little below the surface of the ground. Often several cocoons are there found in a cluster. (See Plate II). Especially will the larvae hibernate in this position if there is a considerable growth of grass or weeds around the tree trunk, because they are there protected from ex-

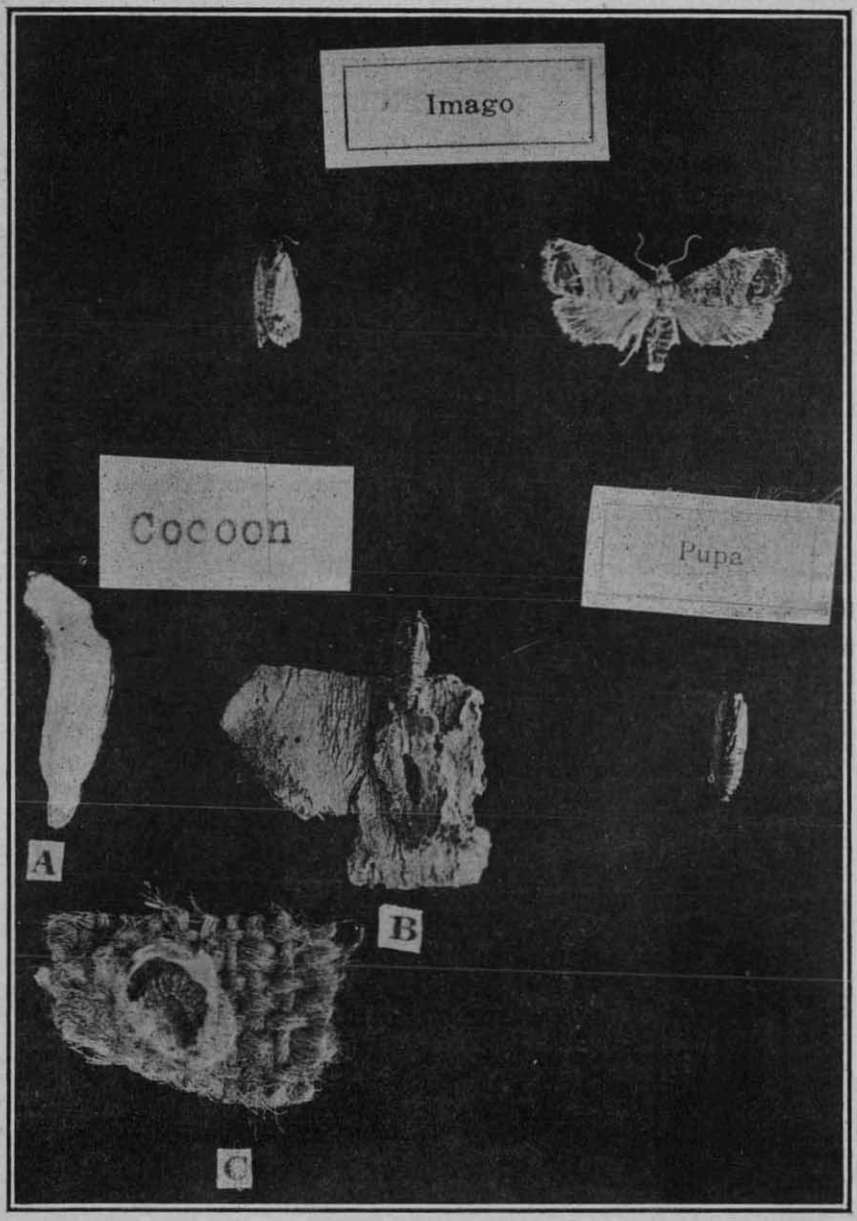

Plate I. Stages in Life History of the Codlin Moth. A. Summer cocoon, more elongated than usual. B. Winter cocoon, showing empty pupa case. C. Winter cocoon showing larva in winter position. x1¾.

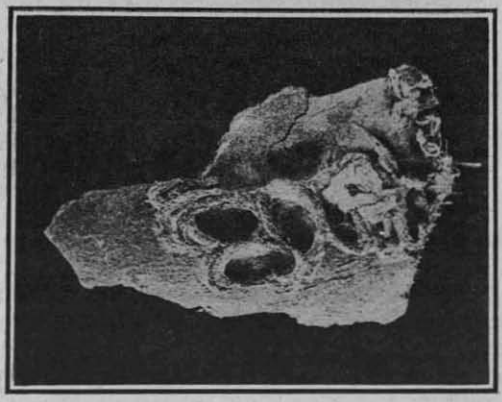

Plate II. Bit of bark with cluster of opened winter cocoons. x1¾.

treme cold and from enemies, such as birds. Very often they spin the cocoons in the ground itself, or in trash on the surface of the ground. Several cocoons have been found, for example, in a bit of hollow weed the size of a pencil and not over three inches long. Varied conditions probably determine the place where the majority hibernate in any particular orchard. Probably the most important of these are as follows: Climate of the locality; the condition of the tree trunks, (whether covered with smooth or scaly bark); the type of cultivation in the orchard, (whether clean cultivation or the use of a hay or a cover crop); the condition around the individual trees (whether trash or grass or weeds are abundant about the trunk on the ground.

Definition of "Broods:"

Over-wintering larvae are the worms that winter from the preceding season. They are largely from the second brood of that season, but there are some first brood worms among them.

Spring pupae are those that are formed by the over-wintering larvae.

First brood, or *spring brood moths* are those that emerge from over-wintering larvae.

First brood larvae are the worms that hatch from the eggs laid by the first brood moths.

First brood pupae are those formed by first brood larvae during the summer.

Second brood moths are the moths that result from the pupation of first brood larvae.

Second brood larvae are the larvae that hatch from the eggs laid by the second brood moths.

The cocoon spun by the wintering larva is more or less elliptical in shape and the larva hibernates in a bent or curled condition. (See C, Plate I). The cocoon has incorporated in its walls more or less trash, such as bits of bark. This material gives more protection to the worm inside. As the temperature rises in the spring the larva often leaves the

old cocoon and migrates to some other point, and spins a new one for protection before pupating. This second cocoon is more elongated than the winter one and has a thin silken partition across it, at a point about three-fourths of the distance from the end where the larva is found. More often the larva pupates in its winter cocoon. In this case the larva remodels the cocoon either elongating it, or else building to the outside a long slender passage-way. It is necessary that the pupa have more room for its formation and transformation and a passage-way is needed for the mature moth. Just before the moth emerges, the pupa wriggles out thru this passage-way or thru the partition to the outer air. About two-thirds of the pupa projects from the cocoon. (See B, Plate I). The moth then has an unobstructed place for emergence. Unless there is plenty of room when it emerges, deformed or broken wings result, so nature has made provision against such an occurrence. Some of the larvae begin to change to pupae just before the apple trees begin to bloom, and continue to change over a period of several weeks until all have become pupae. The pupal stage of this over-wintering brood is approximately three weeks, depending on temperatures at the time. A few precocious moths may be emerging by the time the calices have closed, but the bulk of the brood comes on a little later.

The adult moth has a grayish-brown colored body about three-eighths of an inch long. The wings expanded, measure three-fourths of an inch and are about the color of the body or often darker with wavy lines giving the appearance of watered silk. The hind wings are nearly slate colored. The marking that makes for positive identification of the moth is a large golden brownish spot on the hinder outer angle of each front wing. Some strains of moths are yellowish and others are very dark brown.

A few days elapse after emergence before the female begins to lay eggs. If the temperature is low, no egg laying takes place. It has been found that few or no eggs are deposited unless the temperature is 60 degrees F., or above, at dusk. This is the time when the moths fly about looking for a place to lay eggs. At other times of the day the moths are hiding in crevices or dark places of the tree. Because of their protective coloration they are hard to detect when resting on the bark of the tree, and if the temperature is below 60 degrees F. at dusk the moths still remain inactive.

The eggs, at this time of the spring, require, on an average, ordinarily from 10 to 12 days for hatching. They are small, flattish, glistening white specks, about the diameter of a pin head, and resemble small trout scales. Under the magnifying glass, they show a net-work of lines. The eggs are hard to find but easily recognized when one is familiar with their appearance. At first they are white but after two or three days a red ring begins to appear which grows gradually darker and heavier. A day or so before hatching a black spot appears in the center. This is the head of the tiny worm.

When hatched the larva or worm is very small and at once begins to look about for a place of refuge. It seems to crawl aimlessly about over the surface of the leaf or apple where it is hatched. If hatched on a leaf it eventually reaches an apple, if one is near, unless destroyed in

the meantime. The worm is more than likely to try to enter the apple through the calyx or at a point where a leaf or another apple touches the apple. These points afford protection and possibly the tissues of the fruit are more tender at such places. It is important, therefore, to have the calyx well filled with poison to be ready for such worms as try to enter at that point.

The length of time the worm remains in the apple varies considerably. The average time is about 20 days for the first brood. When the worm is mature it emerges from the apple and makes its way to the ground, or to the trunk of the tree. It soon spins a cocoon under bark scales or in trash on the ground or in the ground itself. This cocoon is thinner, as a rule, than that formed by the over-wintering larva and is longer and otherwise different in shape. It also has the silken partition mentioned previously. (See A, Plate I). The larva may pupate the same day it comes down the tree, but more often waits for from one to several days. On the average four days elapse before pupation. The length of the pupal stage is shorter for this brood, the average being about 12 or 13 days. Some moths emerge as soon as 8 days after pupating.

Within a few days after emergence the moth begins to deposit eggs on the apples. As the weather is warm these eggs hatch quickly, usually in 5, 6, or 7 days. These second brood worms enter the apple and remain there slightly longer on the average than do those of the first brood. When they emerge they descend from the tree and form the winter cocoon. In some warmer regions there may be a partial third brood; some of these second brood larvae transform to moths at once instead of hibernating. In cooler regions some of the first brood larvae spin winter cocoons and remain till the following spring, hence only a partial second brood develops. As the northern limit of apple culture is approached, more and more of the first brood larvae fail to transform to second brood moths, till in the far northern limits only one brood is found. In some of the cooler parts of Idaho, there is evidently only a partial second brood.

Work in the Payette Valley in 1920.

In the life history studies of the codlin moth in the Payette Valley in 1920, two objects were kept in view:

1. The accumulation of data on the stages of the insect that will be of future value in control measures.
2. The determining of the best dates for application of the different sprays for the current season.

Practically every orchard in the district from New Plymouth to a little below Weiser was visited at least once during the season for the making of field notes, but most of the observations were taken in a limited number of orchards, in representative localities throughout the valley. For watching the various stages of the insect, cages of a special type were employed in which to keep the transforming larvae and pupae. (See cover page). The bottom and top were each composed of two boards which were sawed to fit around the tree trunk. The cage was placed just on top of the ground, thus giving approximately natural con-

ditions for the development of the moth. Where the boards did not fit tightly about the trunk the crevices were plugged with burlap or other material to prevent the escape of the larvae. Window screen was tacked around the outside of the cage. The cage was made in two halves, hinged together so that it could be easily opened. In one corner there was a small door, through which material was put into the cage. These cages were placed in representative localities scattered all the way from three miles east of New Plymouth nearly to Weiser.

Wintering Larvae. Several methods were used in the study of the over-wintering larvae.

A. Larvae were collected from around trees early in May and placed in pupal sticks, which are pictured in Plate III.

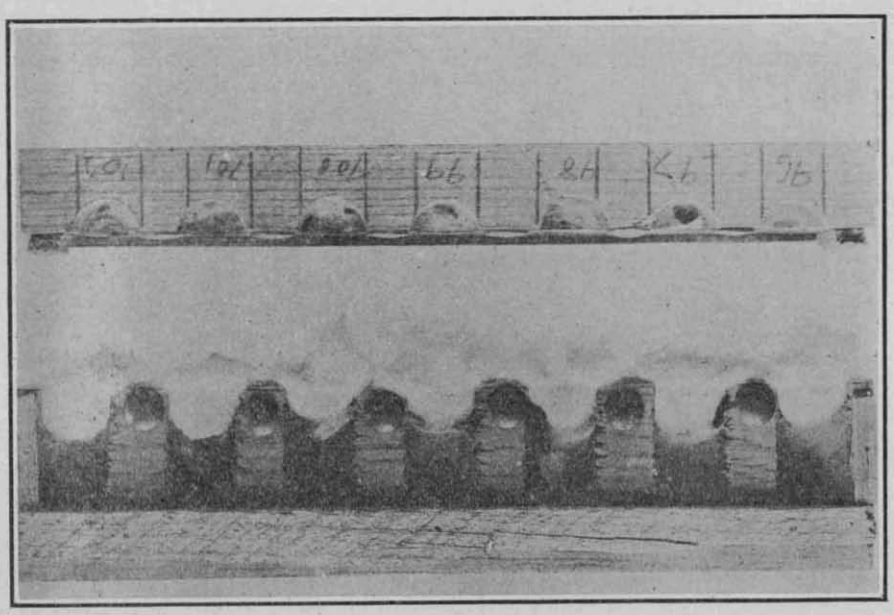

Plate III. Pupal Sticks used in Codlin Moth Life History Studies.

These sticks were 8 inches long, 2 inches wide and three-fourths of an inch thick. As shown in the picture, seven semi-circular holes are cut in one side of the stick, five-eighths of an inch in diameter and about 1 inch deep. A strip of transparent celluloid was tacked on the side of the stick over these holes. The opening to the cavity thus formed is plugged with cotton after the larva has entered. Thus from day to day the condition of the insect can be observed through the celluloid without disturbing it, and dates of pupation of larvae and emergence of moths recorded in the same way as under natural conditions. This method more nearly approximates the natural condition of the codlin moth than does that in which glass vials are employed. The length of time spent in the pupal stage varied from 12 to 27 days, the average being 20.4 days.

B. As a check on these data close observations were made of the date of emergence of moths around trees in orchards scattered throughout the Payette Valley. Two methods were used in collecting these data.

1. Tents of mosquito netting as shown in Plate IV were tacked about the tree and the outside of the tent staked down securely or held with dirt. These tents were watched daily for the emergence of moths. Those which emerged from under the tent commonly flew up on the cloth of the tent, especially towards evening, and were easily seen.

Plate IV. Tent of mosquito netting around base of apple tree. Used in observing emergence of codlin moths.

2. Certain trees were marked and watched daily for the appearance of the empty pupal cases on the trunk or on the surface of the ground. After one becomes familiar with the appearance of the empty cases it is very easy to find them. (See Plate I, B, under cocoon). It is necessary to prevent growth of weeds, etc., near the trees for accurate observation. This method proved more accurate and cheaper than the first method.

Fig. 1 shows graphically the long period over which the moths of this brood emerged. There are really two peaks to the brood, one about June 12, the other about July 1. The reason for this was largely due

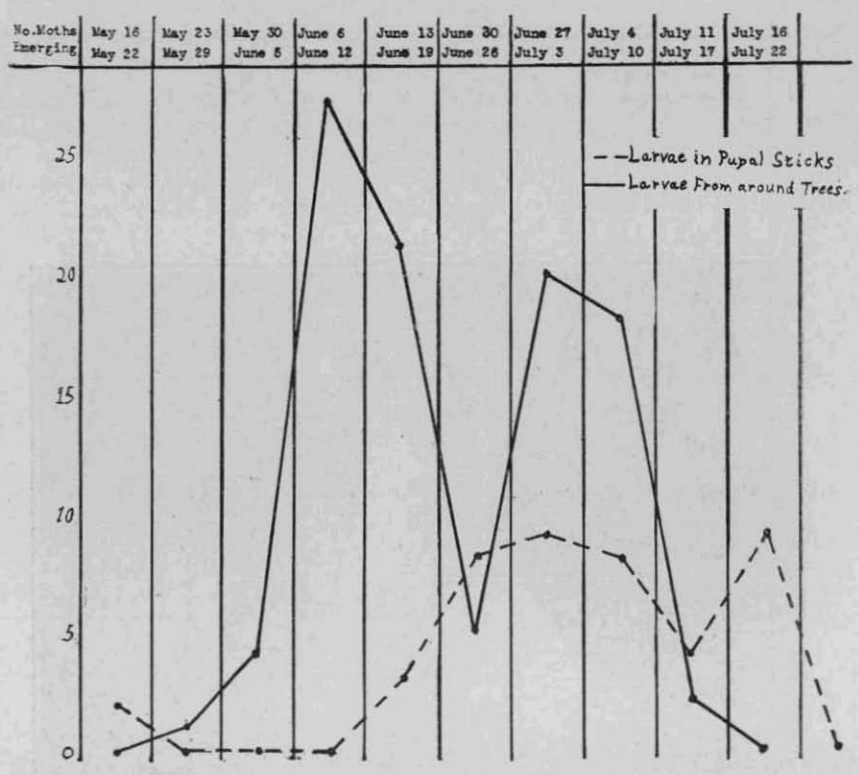

Figure I. Emergence of Moths by Weeks, Payette Valley, Idaho, 1920.

to weather conditions in the spring. By May 5 a few wintering larvae were pupating and from that time on considerable numbers pupated for a time during a spell of fairly warm weather. About the middle of May the weather became markedly cooler so that pupation was largely stopped or delayed. (See Fig. 2). As a result, these larvae already pupated, emerged as the weather grew warmer near June 1, and the remainder then gradually pupated, emerging as a distinct part of the brood, about July 1. The average temperature for May was 2.9 degrees cooler than the 10-year average and for June 1.5 degrees. This abnormally low temperature would of necessity slow down the transformation of the codlin moth.

A study of Figure 1 shows that the larvae kept in the pupal sticks seem to have been delayed in their transformation because of taking them from their cocoons. Part of this delay, however, may be due to the source of the larvae; a large percentage of them came from an orchard which had a heavy growth of grass around the tree trunks. Notes kept on the larvae in this orchard show that in their natural conditions they were also very late in their transformation.

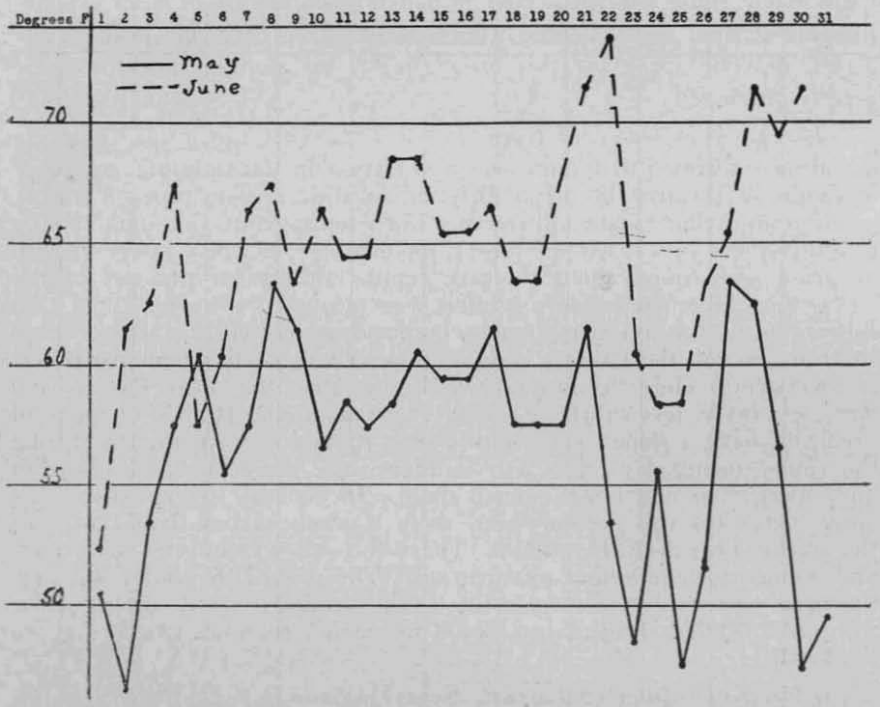

Figure 2. Mean Daily Temperature for May and June, 1920, at Payette, Idaho.

Relation of Emergence of First Brood Moths to Time of Spraying. It will be noted that a few moths had emerged prior to June first, some even as early as May eighteenth. However, it was not until June first that the proper temperatures obtained for the laying of eggs by the codlin moth. So, in dating the application of the first cover spray for this brood, these first emergents were disregarded. In general, it was recommended to commence spraying not later than June tenth, with the understanding that spraying be well along by the fourteenth of June, which would be 14 days from the time when the moths commenced depositing eggs. It was found further, that, except in one or two orchards with peculiar conditions, no worms were entering apples before this date. Very soon after that time hatched worms were abundant in many orchards. So it was very evident that in 1920 in the Payette Valley, the codlin moth waited for suitable temperature before laying its eggs.

The spray, which was generally applied between June tenth and fifteenth, would take care of the early part of the first brood until approximately the time of the second peak of the brood. Before this peak, a second cover spray was needed; that is, a second spray should have been applied two or three weeks after the first spray. Those who applied an additional spray at this time had, for the most part, rather clean

fruit, while some who neglected it had an abundance of later worms. In more normal seasons there would probably be only one peak to the brood and one spray for this brood might be enough, unless it were greatly prolonged.

Variation in Dates of Spraying in Different Localities. The observations indicated that there was a variation in the time of emergence of moths of the first brood in different localities. The type of culture given in an orchard made a difference in the emergence, due undoubtedly to a difference in soil temperature. For example, where a heavy growth of grass was found about the tree trunks the transformation of the larvae that hibernated below ground was delayed. However, those that hibernated on the tree trunk emerged comparatively early. It was noted that, in general, the Payette Heights district was earlier than the others in the valley. Here the ground was higher than that near Payette and was, seemingly, less subject to frost. Certain orchards also, or parts of orchards, have a slope to the south; such spots warm up rapidly during the sunny spring days. As a consequence the larvae transform earlier and emerge sooner from the pupal stage. In general, it seemed that the spray dates for this section were about a week earlier than those for the section near New Plymouth. There the soil was heavier, as a rule, and seemed to take longer to warm up. The rest of the valley was, for the most part, midway between these two localities. As a consequence, the recommended spray dates should be varied somewhat according to the locality.

Effects of Winter on Larvae. Several points in the northwest in the spring of 1920, reported that a high percentage of the wintering larvae were destroyed by the abnormally low temperatures of the preceding winter. In the Payette section such results were not found. Possibly this was due in part to the fact that in most orchards observed the large majority of the worms hibernated near or under the surface of the soil, thus being protected from the low temperatures. Counts made at one place near Payette showed on the average twenty-three per cent of the larvae were dead from some cause, probably from the low winter temperatures. In this orchard a rather high percentage of the larvae were farther up on the trunk. In certain other orchards where the larvae were lower down, being either near or below the soil surface or protected by grass or weeds, only one to two per cent were found dead. It is safe to state that in the Payette Valley, the average of larvae killed by the winter was less than ten per cent so that this factor in the control of the larvae was practically negligible.

Overlapping of Broods. An interesting point was noted in the orchard of Mr. Moulton. Counts of larvae made on June twenty-eighth showed some still in the winter position. Several days at least would elapse before these larvae remodeled their cocoons or migrated for the purpose of pupating. Other orchards revealed larvae nearly as belated. Figure III shows that on June twenty-ninth larvae of the first summer's brood were already coming down the trees and by July first some of these had already entered the pupal stage. That would mean that the two broods overlapped at least several days.

Enemies that Destroy the Wintering Larvae. Besides the cold of winter, there are several agencies that reduce somewhat the number of wintering larvae. Probably birds destroy the largest number, those of the Woodpecker family working the greatest havoc. These birds are active more or less thru winter and spring and find and destroy codlin moth larvae wherever they are exposed. There is undoubted value in having the space just around the tree free of grass, weeds, or trash of any kind that will afford protection or hiding to the hibernating larvae, so as to force them to spin their cocoons as much as possible on the exposed trunk of the tree. Then they can be more easily found by birds, and are also more likely to be injured by low temperatures.

Since a large number of larvae migrate from the winter cocoons to other places before pupating they are exposed to certain predaceous insects whose natural food is scarce at that time. Several cases were noted in our studies, where the migrating larvae, while crawling about on the trunk of the tree, were seized and carried away by ants and spiders, both of which are abundant in the spring on apple trees in the Payette country.

Egg Laying by First Brood Moths. As noted previously the egg of the codlin moth is a small white glistening speck, rather difficult to find. Eggs were not found in the Payette Valley before June eleventh. Previous to that date only a small number of eggs had been laid in the orchards in which search was made. In one orchard, worms were found entering apples on June twelfth and as the average time required for hatching at this time of the year is from 10 to 12 days, it is evident the moths began laying eggs about June first. By June sixteenth the eggs were easily found in most orchards, having become very plentiful at that date. The peak of the egg laying for the first part of the brood was June 11-14, 1920.

Position of the Eggs of the First Brood Moths. Various writers have reported somewhat differently on the position in which the eggs of the moth are laid. Melander [1] states that the eggs of the first brood are laid on the upper side of the leaves, while those of the second brood are laid almost entirely on the apple.

On June twenty-fourth, which was after the time when the peak of the first part of the brood was hatched, counts were made as to the position of the eggs. These counts were made in an infested orchard which had not been sprayed during the two previous years, but received two sprays in 1920, though not at the proper times. The following number of eggs were found:

On apples	47
On upper sides of leaves	20
On the lower side of leaves	4
On twig	1

These counts include all eggs laid up to this date; hatched as well as unhatched. It is interesting to note that where eggs were laid on leaves, they were for the most part on the upper side of the leaves, which are smooth; that is, practically free from downiness. Of those found on the lower side of the leaves, all were on the leaves of a particular

1. A. L. Melander— Bull. 77, Wash. Experiment Station, 1906.

variety, that were practically smooth on the lower side. Also in no case was an egg found in such a position that the newly hatched worm would have to crawl more than five inches to reach an apple. Always the eggs were on leaves attached to a fruit spur that had one or more apples on it. Not one egg was found on leaves attached to twigs and branches far from a bearing spur.

Noteworthy too, is the fact, that up to this date (June 24, 1920) practically two-thirds of the eggs had been laid on the fruit itself, and, too, all the freshly laid eggs found on that date were on apples. Those on leaves were hatched or about to hatch. The indications were that the first moths of the brood laid their eggs largely on the leaves, but as the season advanced more and more were deposited on the apples till by the date mentioned, all were being laid on the apples. Figure I shows that a considerable portion of the brood emerged after June twenty-fourth; which means that in the Payette Valley, probably eighty per cent of the eggs of the first-brood moths were laid on the apples. Possibly this may not always be the case. Because of the cold spell in May, considerable time elapsed after blooming of the apples before egg laying commenced; as a consequence, the apples attained considerable size before egg laying became general and seemingly an unusually large proportion of the moths found the apples.

But the question occurs: If the moth when laying eggs on leaves, chooses only leaves on spurs with growing apples on them, why does not she lay them directly on the apples? It has been suggested, that the moth avoids the apples when very small because they are slightly downy at that stage. The downiness largely disappears as the apple grows, so that later it is no longer avoided. This opinion is strongly supported by the data showing that the eggs on leaves are only found where the surface is nearly free from downiness.

First Brood Worms. The first worms of this brood were observed on June twelfth in the Payette Heights section. As noted thruout the season this section seemed to be slightly earlier in every respect than most other points in the valley. The peak of hatching of the first part of the brood occurred between June 19-23, 1920, after which date there was a quick falling off of worms entering apples, with another sudden rise early in July.

Entrance of the Larvae into the Apple. Observations taken on the newly hatched worms showed that they had a habit of crawling about over the apple for some time before entering. They are very small at this time and probably feed on the leaf or apple when first hatched, previous to excavating an entrance thru the skin. The early hatched worms are thus liable to be poisoned on the leaf, before reaching the apple. This fact shows one reason why the calyx spray is valuable; at the time of application of the calyx spray, the leaves immediately surrounding the cluster of blossoms are pretty well grown, but the other leaves that later cover the tree are only just developing. That makes it possible, in the operation of filling the calices with poison to give these leaves on the spur a good coating, especially on the upper side, where the bulk of the early eggs are deposited. The calyx spray then takes care of the earliest hatched worms, making it safe to delay the following

spray until the worms are actually hatching, thereby throwing later the date at which it is still effective. This often makes it possible to omit one spraying; that is, the second spray for the first brood.

Appearance of First Worms Under Bands. About the middle of June a number of trees in various parts of the valley were banded with burlap so that data could be collected on the emergence of the larva from the fruit. A strip about one foot wide was cut of sufficient length to easily go around the trunk of the tree near the ground. Either a tack was used to hold it in place or the ends were hooked over a nail. In some cases a piece was used about a foot longer than necessary to go around the tree trunk. The loose end was tucked under the band to hold it in place and thus a nail was unnecessary. These bands were observed three times a week. Figure 3 is a graphic representation of the season's band record for a number of places scattered throughout the valley.

One may observe that after the worms commence to appear under the bands there is no break in their appearance; that is, no distinction is seen between the first and second brood. That is what would be expected when we consider the overlapping of the emergence of the moths of the first and second broods. After the peak of the first brood was reached in the week of July 18-24, 1920, a decline was found in the number of larvae under the bands till the week of August 22-28, 1920, when a slight rise occurs. It would be expected that the worms of the second brood would begin to come down in noticeable numbers about August fifteenth. This would account for the rise during the week of August 22-28, 1920. Evidently this rise occurs at the time when the first brood larvae have practically all emerged from the apples for there is a steady decline from this date.

Pupation of First Brood Larvae from Bands. The larvae from bands in certain selected orchards were immediately placed in pupal sticks, which were kept in the cages mentioned and their development watched till the moths emerged. Most of the larvae immediately spun cocoons, although some of the larvae pupated at once after coming down the tree. Others remained in the larval stage for several days, the period varying from 1 to 19 days, the average being 5 days. It was observed when larvae delayed their pupation for a long period no moths emerged, the pupae dying at some time before transformation was complete. That is, no moth emerged from a pupa formed by a larva that delayed its transformation into a pupa more than ten days. All those that took a longer time died some time in the pupal stage.

Length of Pupal Stage of First Brood Pupae. The observations on the larvae in the pupal sticks covered only those coming down the tree previous to August third. The length of time spent in the pupa by those under observation in our cages varied from 7 to 21 days. The average number of days spent in the pupa was 11.6 days.

Relation of Band Record to the Sprays for Second Brood. From these tables it will be evident that a fairly accurate forecast can be made as to the time the first worms of the second brood will be hatching and entering the apple if the date is known when the first worms begin to come under the bands. The worm remains five days in the larval stage

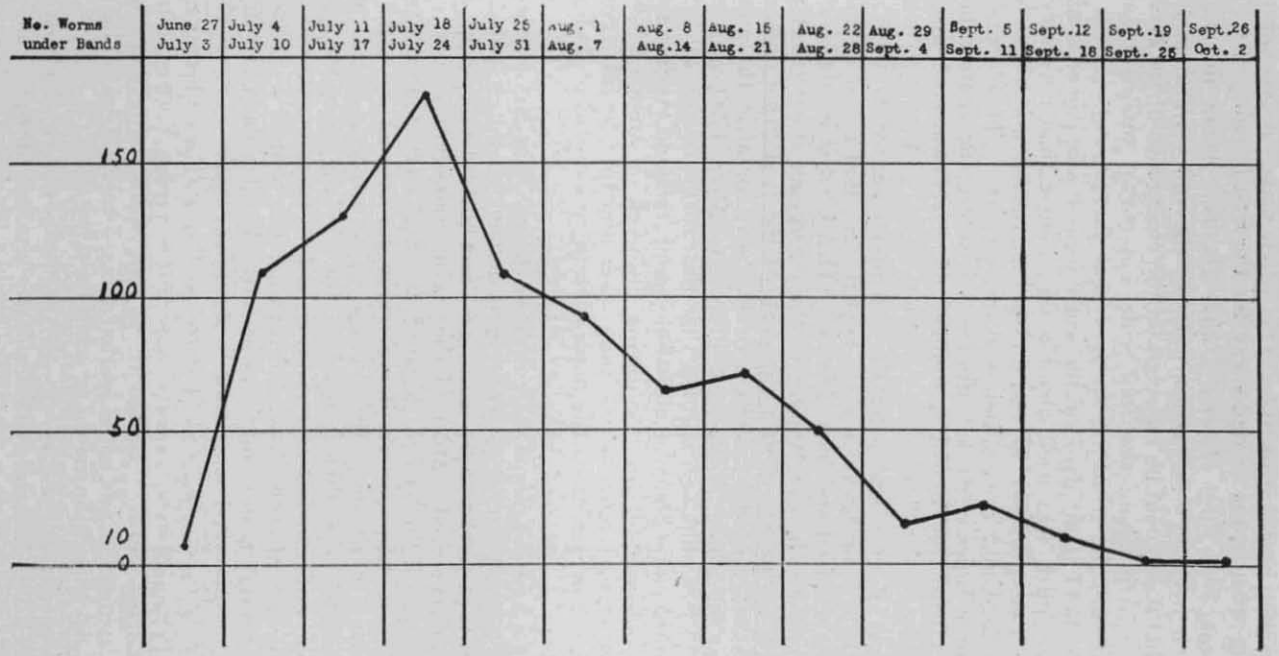

Figure 3. Band Record by Weeks, Payette Valley, 1920.

before pupating. Twelve days is the average length of the pupal stage. Three or four days usually elapse after the moth emerges before it begins egg laying and the eggs at this date require six or seven days for hatching. This gives a total of twenty-six to twenty-eight days from the time the worms come down the bands. Inasmuch as in some cases these stages are somewhat shortened a period of twenty-five days seems about right for use in computing the date for the second spray. Worms were found under bands in Payette Heights on June 29, 1920, and it was recommended that spraying for the second brood be pretty well completed in that section by July twenty-third, which would be twenty-five days later. A few worms were actually found entering apples in that locality on July twenty-second, showing that the twenty-five day period was none too long to use in reckoning the date of the spray for the second brood. In case only one spray is to be applied to control the second brood, it might be delayed a day or two more so as to have it more effective throughout the peak and towards the end of the brood. In case an additional spray for the second brood is to be applied this twenty-five day period might better be shortened a day or two in the Payette Valley, if the temperatures were continuously high throughout the period.

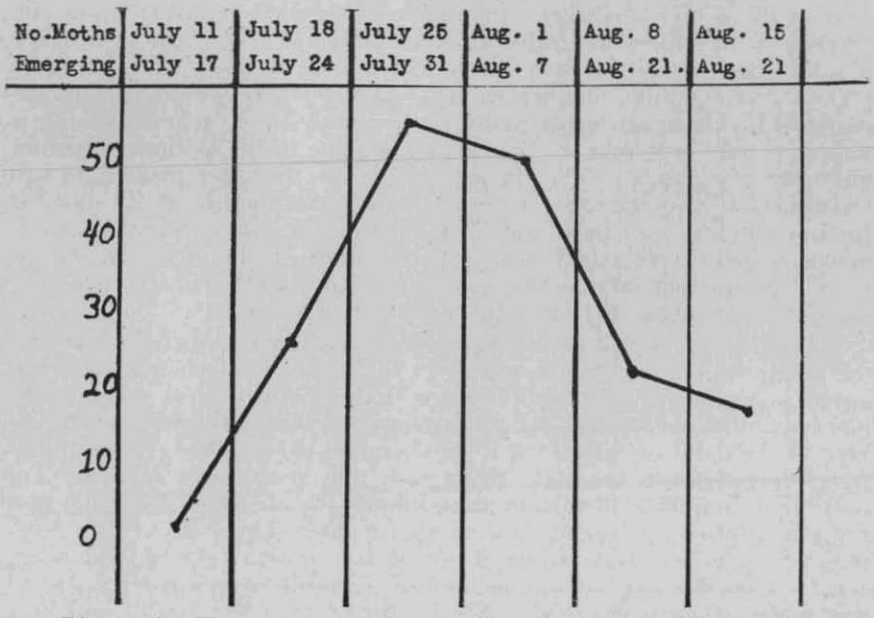

Figure 4. Emergence of Second Brood Moths by Weeks, Payette Valley, 1920.

Emergence of Second Brood Moths. Figure 4 sows emergence of the second brood moths up to the week of August 15-21, 1920. No more observations of this phase of the work were taken after that time.

Survival of Moths Without Apples. This question continuously recurs. No data were collected on this point in the work at Payette. In our opinion in the Payette section there would be no reason to believe that the worms would grow to maturity on trees that had no apples. Melander [1] gives results of some experiments in this line in the Yakima Valley. He found that while the worms fed for a time on apple leaves alone, one even as long as two weeks, they did not increase in size to any extent. He concluded that in that hot and dry climate it was impossible for the codlin moth larvae to mature if fed on apple leaves only. On the other hand, Hammar [2] while working in Michigan came to a different conclusion. He reared worms on apple foliage alone, and in one case a worm transformed to a pupa which was only two-thirds natural size. This pupa later died. He concluded that in that section it might therefore be possible to perpetuate the species that way in case of total failure of the apple crop in any year. In the districts of the northwest, this is a remote possibility.

Survival of Larvae for More than One Year. From the observations made at the orchard near Weiser it was evident that possibly under some conditions larvae might not pupate the first year but might hibernate a second time and emerge the following year. As late as the first week in July some of the worms showed no indication of pupation, but were in the winter condition. Inasmuch, as these larvae were below the surface of the ground on trunks of trees protected from heat by a heavy mat of grass, it seemed very likely that a few of them were going to stay in that condition another winter. This possibly would explain the reason why there are often many codlin moths in a year following a season of total crop failure. Hammar [2] in some of his cultures of codlin moth observed such a delay in pupation. One larvae remained for 20 months, over two winters, before dying. Another lived 23 months, finally changing to a pupa, and dying before the moth emerged. Inasmuch as these were under abnormal conditions as to moisture, etc., it is very likely that larva often pass thru two winters, finally pupating the following spring, the pupa later giving rise to moths.

Length of Time in the Apple. Some data were collected regarding the length of time the worm spends in the apple. Search was made on apples on a number of trees for eggs of the moth. These apples were marked and watched daily for the hatching of the eggs, and record was kept of the dates on which the worms entered the apples. These apples were bagged for a few days to prevent the spray from reaching and possibly penetrating them and thus killing the worms. Bagging also prevented other eggs being laid on the apples. These bags were soon removed. A few days before it might be expected the worm would emerge from the apple it was picked and carefully watched from day to day to see when it emerged. The length of time the larvae remained in the apples varied from 13 to 31 days; the average being 23.7 days.

Number of Broods in the Payette Valley. The idea has been prevalent in the Payette Valley that there is a partial third brood of the

1. A. L. Melander—Bull. 77, Wash. Experiment Station, 1906.

2 Hammar, A. G.—Life History of the Codlin Moth in Michigan. Bul. No. 115, Part 1, U. S. Dept. Agr. Bur. Entom.

codlin moth in that section. This idea arose because of the abundance of small worms entering apples, often as late as the time of the picking of the early winter varieties. The data collected, while not complete for the latter part of the summer, indicate that those late worms were merely the progeny of the latter part of the first brood. In fact, the data show that there was not even a complete second brood in 1920. It was found that many larvae in the pupal sticks did not pupate, but spun a winter cocoon and assumed the bent condition preparatory to hibernating. This was especially noticeable in the latter part of the brood. The overwintering brood was thus composed of the second brood worms and a considerable percentage of the first brood worms. Possibly in seasons with a higher mean temperature for the early months of summer, a partial third brood might develop.

Temperatures for Hatching Eggs. As noted above the earliest laid eggs of the first brood require a much longer time for hatching than do those laid later. Hammar [2] worked out the average period required for hatching depending on the temperatures. He determined that the eggs required 15 to 16 days when the mean daily temperatures were about 60° F. This time gradually grew shorter as the temperatures were higher. For example, at a mean temperature of 65° F., 10 days were necessary to hatch the eggs, at 70° F. seven days and at 83.6° F. only four days were necessary. This is of importance in computing the time for the various sprays. The periods usually arbitrarily adopted for dating sprays should be somewhat shortened or lengthened, depending on whether the temperatures for those days are abnormally high or low.

Experimental Spraying. In two orchards some experimental spraying was conducted to throw light on certain points. In the orchard of Mr. B. P. Shawhan near Payette, an experiment was outlined in which several combinations of sprays were used, certain sprays being omitted. Unfortunately, owing to a mistake at harvest time, the fruit from some of the trees in the experiment became mixed, consequently less data were secured than was anticipated. Mr. Shawhan applied two calyx sprays, the first was applied May nineteenth, the second calyx spray a week later on May twenty-sixth, after most of the calices were closed. A third spray was applied on June sixteenth, the fourth on July thirtieth, and the fifth about three weeks later. No spray for the second part of the first brood was applied. Two young Jonathan trees were included in each block, and these did not have a heavy crop of fruit. This section of orchard had been very wormy during 1919. This was especially true of some MacIntosh trees mixed in between the Jonathan. Practically all of the fruit of the MacIntosh during 1919 dropped to the ground because of worms. As will be noted from Table I a good control was obtained during 1920.

2. Hammar, A. G.—Life History of the Codlin Moth in Michigan. Bul. No. 115, Part 1. U. S. Dept. Agr. Bur. Entom.

Table I.

Counts of Fruit from Jonathan Trees. Experiment in B. P. Shawhan's Orchard.

	1st Block	2nd Block	3rd Block	4th Block
	1st Calyx Spray Omitted	Both Calyx Sprays Omitted	2nd Calyx Spray Omitted	Check Trees
Apples at thinning time	No.	No.	No.	No.
Perfect	811	671	673	1063
With calyx worms	12	34	0	0
With side worms	30	66	16	2
Per cent worms at thinning time				
Calyx worms	1.4	4.4	0	0
Side worms	3.4	8.5	2.3	.2
Total per cent	4.8	12.9	2.3	.2
Apples at picking time including windfalls				
Perfect apples	415	450	248	410
With healed stings	125	169	33	71
With unhealed stings	51	125	7	17
With calyx worms	6	114	0	0
With side worms	13	77	0	6
Per cent worms at picking time				
Calyx worms	1.0	12.2	0	0
Side worms	2.1	10.0	0	1.2
Total	3.1	22.2	0	1.2

At Mr. John Moulton's a similar experiment was carried on using five blocks of two trees each. The plan of this experiment was to omit the spraying of one block (two different trees) for each of the five sprayings. By a misunderstanding no trees were omitted during the fifth spraying. The trees were Ben Davis. There were a large number of larvae hibernating on the trees, from 10 to 25 on each tree, making it certain that there would be many moths. Mr. Moulton applied five sprays as follows: Calyx spray May 17, 1920; second spray June 13, 1920; third spray June 29, 1920; fourth spray July 27, 1920; fifth spray August 17, 1920.

Table II.

Counts of Apples from Ben Davis Trees. Experiment at John Moulton's.

	1st Block	2nd Block	3rd Block	4th Block	5th Block
	Calyx Spray Omitted	2nd Spray Omitted	3rd Spray Omitted	4th Spray Omitted	Check Received 5 Sprays
Apples at thinning time	No.	No.	No.	No.	No.
Perfect	1126	202	622	274	328
Calyx worms	18	0	2	0	0
Side worms	37	7	6	1	1
Per cent worms at thinning time					
Calyx	1.6	0	.31	0	0
Side	3.2	3.3	.94	.36	.3
Total per cent	4.8	3.3	1.25	.36	.3
Apples at picking time windfalls included					
Perfect	495	257	665	548	686
Healed stings	336	180	197	198	323
Unhealed stings	63	83	76	110	153
Calyx stings	58	4	2	3	0
Calyx worms	59	19	5	4	11
Side worms	56	31	43	40	34
Per cent worms at picking time					
Calyx	5.5	3.3	.5	.4	.9
Side	5.3	5.4	4.3	4.4	2.8
Total per cent	10.8	8.7	4.8	4.8	3.7

NOTE—"Calyx stings" is a term used to denote apples where a worm enters the calyx and eats for a time, later dying. There is a discolored place in the calyx end of apple but this does not show greatly on the outside.

In view of the fact that there has been some advocacy of omitting the calyx spray, these tables are of significance. If there are many worms hibernating in the orchard it seems unquestionable that a calyx spray should be applied. If there were not many worms wintering over, an orchardist might dispense with a calyx spray for a series of years, provided he was very careful with the first spray for the first brood. But in a section such as the Payette Valley where years of good crops often alternate with years of poor crops, there are always orchards where worms are plentiful, due to neglect of growers to properly spray when crops are short, and if there are orchards near by with heavy infestation of codlin moth, it will be only a question of time when an orchard where no calyx spray is applied is invaded. It seems, therefore, that the calyx spray is good insurance against an infestation of worms. Besides, as noted before, if a good calyx spray has been applied the next spray can be somewhat delayed. This might often result in making unnecessary the second spray for the first brood, and thus nothing would have been gained by omitting the calyx spray. It seems best, therefore, to recommend the application of the calyx spray. Our observations however, indicate that its value in the past has been somewhat over-estimated.

Spray Gun Versus Spray Rod. Since the introduction of the spray gun there has been considerable discussion of the merits and demerits of the

spray gun as compared with the spray rod. Most authorities have come to admit that for the cover sprays, the gun is equal to the rod if properly handled, but some have maintained that the gun was not so efficient for the calyx spray. The contention has been made that the rod could present a driving spray in such a position that the calyx cup was more easily filled. Childs [3] found that the gun was as efficient as the rod in calyx worm control if properly used. The spray must be applied under high pressure so it will be a fine mist throughout the tree, clear to the top. The principle is that the fine mist settled into the calyx cup making it unnecessary to force the spray in at close range as is accomplished by the rod.

The observations at Payette in 1920 indicated that a good man can do good work with the spray gun not only in the cover sprays but also with the calyx spray. The spray was applied with guns in both the orchards where experiments were conducted, and the check trees showed good calyx worm control. There seemed danger, however, that a careless workman would do poorer work with the gun than with the rod. It resolves itself largely into a question of men. If the men doing the actual spraying are careful and reliable, or if close enough supervision can be exercised over them, the gun is at least as efficient as the rod for all kinds of spraying.

Amount of Poison to Use. The belief has become prevalent in many sections that if 4 lbs. of arsenate of lead to 200 gallons of water is sufficient, then 6 or even 8 lbs. would be even better. Repeated experiments have shown that 4 lbs. of lead arsenate to 200 gallons of water is sufficiently strong to kill the codlin moth larvae if they eat it. In fact a much weaker solution is sufficient. As a result of a series of tests Lovett [4] recommends 3 lbs. to 200 gallons for the earlier sprays, increasing the dosage to 4½ lbs. for the later summer sprays.

A more efficient use of the extra 4 lbs. per 200 gallons of water would be to put it into an extra tank of water and spray the tree more thoroughly. Few people in spraying cover the fruit on all sides thoroughly. It the apple has been wet on all sides with spray at the rate of 4 lbs. to each tank there will be poison enough left on the apple to kill any worms that try to enter at any point. There is more likelihood of getting poison on all sides of the apple by applying 8 lbs. of lead arsenate in 2 tanks (400 gallons of water) than if it were applied in one tank. A heavy deposit of poison on one side of the apple is of little value if the worm decides to enter the side with no poison. Inasmuch as the investigations at Payette revealed the fact that growers in general were too careless or too hasty in their work to properly cover the apples, it seems best to recommend that the poison be applied at the rate of 4 lbs. powdered arsenate of lead per 200 gallon tank with a possible increase to 4½ or 5 lbs. for the later applications.

General Observations Concerning Spraying Procedure in Payette Valley. The primary motive of the work at Payette was the gathering of data to determine if possible why in certain seasons there were many

3. Childs, Leroy—Oregon Agr. College Exp. Sta. Bul. No. 171.
4. Lovett, A. L.—Insecticide Investigations—Oregon Agr. Col. Exp. Sta. Bulletin No. 169.

wormy apples in the valley. The observations indicated that the chief underlying causes of periodic infestation of worms were as follows.

1. Careless spraying in short crop years.
2. Insufficient number of spray outfits.
3. Careless methods of spraying.
4. Inattention to proper time of spraying.

Careless Spraying in Short Crop Year. Due to severe frosts at blooming time or soon after, the Payette Valley is subject to years of short crop alternating with years of extraordinarily heavy bearing. In years when there are only a few apples in the orchard, there is a tendency for growers to neglect regular spraying. A half dozen apples to a tree will be sufficient to breed moths enough to ensure an unusually heavy infestation of worms the following year. If the worms winter over it is impossible to prevent damage, no matter how thoroughly one sprays. This is indicated in Table No. II. In 1920 the trees were kept sprayed very thoroughly; more so than the average spraying. As will be seen the number of worms that matured was small. There was, however, a high percentage of apples with healed stings which threw those apples at least to C grade. Besides this, there was a high percentage of apples with unhealed stings which went into the cull pile. No matter how thorough the spraying these stings could not have been prevented. In fact these stings are really an evidence of thorough spraying, otherwise many of them would have been worms.

It is good insurance for the following year to spray thoroughly in years of short crop if it does not pay in money returned during that year. In case there were only a fruit or two left on a tree it would likely be more economical to remove all of these fruits by hand before worms matured in them, rather than to spray the whole tree.

Insufficient Number of Spray Outfits. In parts of the valley there are not enough outfits to spray the trees within the dates when spraying would be effective. Especially is this true in the New Plymouth district. Here many orchards are sprayed by custom sprayers; one man often has so many acres to spray that by the time he gets to the last orchard many of the worms are doing considerable damage. This condition can only be remedied by having more spray outfits available. Many spray outfits are old and inefficient and should be replaced by new ones.

Careless Methods of Spraying. Many growers have little idea of the reason for spraying. They only know they must spray and their idea is to get thru it as easily as possible. As a result, the work is often performed in a perfunctory manner. Much of the actual holding of the nozzle is done by hired men, who get careless unless continually watched and checked up on their work. Because of the recent high cost of labor the tendency has been to apply less liquid than needed and to try to make up for this lack by using more poison to a tankful. Close observations in orchards throughout the valley indicated that the average grower was not using the proper precaution in insuring that his fruit was kept well covered on all sides with the spray.

The most marked fault was the failure to put poison on all sides of the apples. As noted above, the worms crawl about for some time before entering the apple, undoubtedly feeding in the meantime. This accounts for the fact that fairly good control was obtained for they would get poison enough to finally kill them, even if they finally did start to enter the apple where there was no poison. But in the case of an apple which has poison only on one side there is an excellent chance of the worm getting in without being poisoned. It seems most important therefore, that the growers use greater care in spraying or in carefully supervising his workmen. Often it would pay the orchard owner to do nothing but watch and insure that his men are spraying properly. The nozzle should be directed at the tree from as many as six different angles. It should be directed up into the center of the tree from below and turned about in all directions inside the framework of the tree. If the tree is tall it will be better to have one man with a spray gun on a tower or platform to properly cover the tops of the trees. Always be sure when a tree has been sprayed that the apples have poison on all sides of them.

Inattention to Proper Spray Dates. An examination of the Figures 1-5 will show that there were periods when the worms were numerous and other dates when they were scarce or even lacking in some orchards. Figure 5 gives a graphic summary of the life history of the stages of the insect in the Payette Valley during 1920, and the dates are indicated when in general spraying would have been most effective. The dates recommended were in general for the whole valley and would vary a few days for certain localities and individual orchards. In most cases where the spraying was done within these dates fairly good control was obtained. In some cases where the sprays were too long delayed a high percentage of worms resulted.

Up to the season of 1920 and to some extent during that year, the growers in general have followed the hit and miss method in regard to dating their sprays. Many would wait until they saw their neighbors spraying before starting with the result that often they were too late for best results.

The data collected during 1920 indicate that spray dates set for a section like the Payette Valley will only be general and will not necessarily be the best for certain orchards. In fact, to determine the best date the individual growers should make their own observations, commencing early in the spring and continuing throughout the season. By doing this the grower will be able to know exactly the stage of the moth at any time in his orchard and will have a good idea of the relative abundance or scarcity of the pest from year to year. The next best method would be the plan followed in some districts: A man is hired to keep track of the insect for a certain limited locality and he is thereby enabled to make rather exact determination of the proper date to spray.

Following is an outline of the procedure that can be easily and profitably followed by any orchardist. In all this work it is pre-supposed that the calyx spray will be applied at the proper time, that is, just after the petals fall and before the calyx cups close.

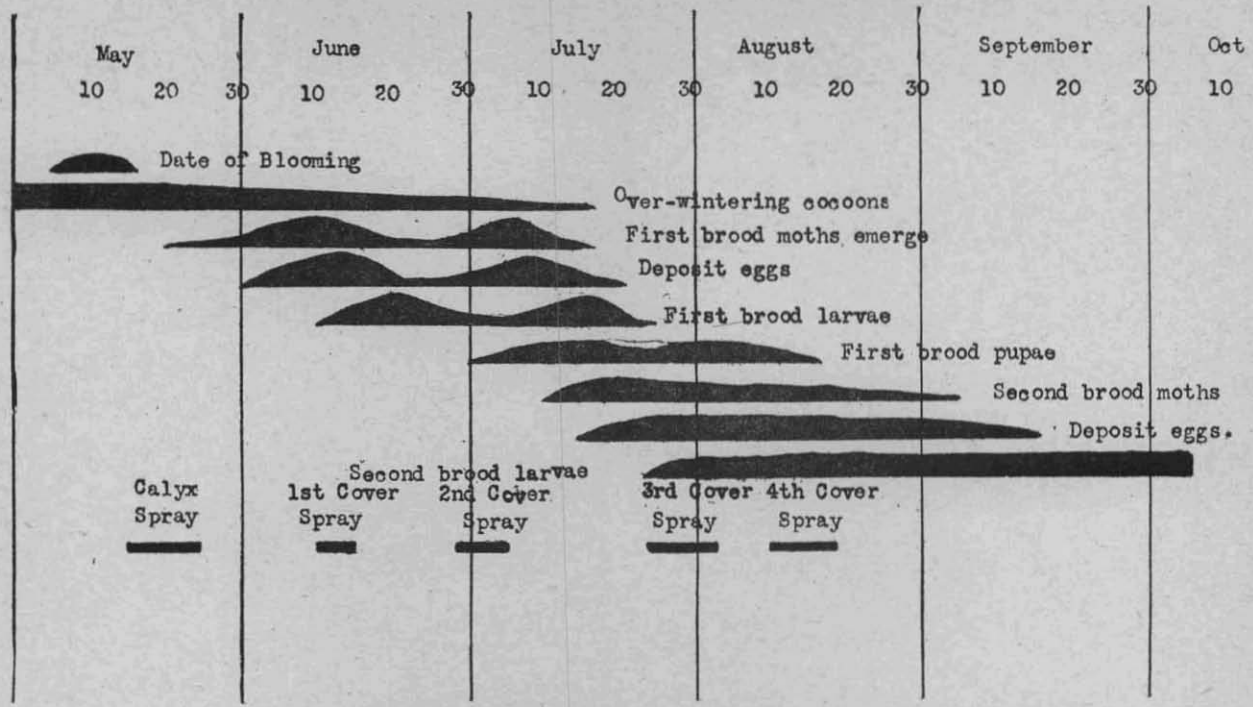

Figure 5. Summary of Stages in Life History of the Codlin Moth in the Payette Valley 1920, Giving Blooming Period of Apples and Dates When Sprays Would Have Been Most Effective.

1. Designate certain trees in various parts of the orchard for observations for emergence of the first brood moths. At least 10 to 20 trees should be marked. If possible select those known to have had wormy apples the previous season. Where there are several types of soil or different methods of culture in use in the orchard include all of them. If there are slopes include trees at the bottom as well as at the top. Bear in mind that the soil on a south slope warms more quickly than a north slope, and consequently there will be some variation in the stages of the insect in these places. Examine the trees at least every other day to find the empty pupa cases sticking out of the bark of the tree trunk or else out of the ground just around the trunk. (See Plate I B). The tents mentioned above can be used for the same purpose if desired. Count 14 days from the time these cases are appearing in numbers for the date of the spray for the first part of the brood, provided the temperature of 60° F. is reached at dusk. If it is cooler, wait until the day that temperature is reached and figure 10 to 12 days from this date, depending on how warm the intervening days are.

Continue observations as to moth emergence, keeping a record of the number appearing on each day the observations are taken. If the brood emerges over a long period a spray two or three weeks after the other should be applied to destroy the latter part of the brood. Apples are growing rapidly at this time and the effectiveness of the spray is greatly reduced by the end of three weeks.

In connection with this spraying program much can be done to prevent second brood worms by thinning the fruit in the period just before the bulk of the first brood worms emerge from the apples; which was, during 1920, in late June and early July. Pick off all apples that have worms and destroy them. This will prevent second brood moths from hatching and will greatly reduce the number of the second brood worms.

2. Some time early in June, band 15 or 20 trees with burlap as indicated above. Watch them at least every other day for appearance of the worms coming down the tree. When the first worms are found under the bands count 25 days later as the date for the application of the first spray for the second brood. If the weather is unusually hot it may be necessary to cut this time a day or two, and if unusually cool lengthen it correspondingly. If the worms continue to come down abundantly for several weeks it will be necessary to apply an additional spray two or three weeks after the other to control this brood. This will always be necessary if there is an abundant infestation of the orchard and if the first brood is prolonged as in 1920. If the worms that winter over are few, or the brood is not prolonged over a long period, possibly one spray for the second brood may be enough. For the Payette Valley section as a whole the indications are that two sprays are needed for the second brood. The only time when the second might be omitted is in the case of an orchard where close observations have been made throughout the spring and summer, and it is known that there will be few or none of the late worms. As remarked before, it is good insurance to apply the second spray for the second brood. On the other hand, it may happen that due to a long warm season in late summer or early autumn,

that a further application may be necessary about two or three weeks before the picking time of the early varieties. There are seasons where there are many so-called "pin worms" at picking time. Ordinarily this sixth spraying will be unnecessary.

SUMMARY

1. During 1920 in the Payette Valley the time of emergence of the first brood was greatly prolonged apparently by the abnormally low temperatures during late May. The emergence extended from May eighteenth till nearly the middle of July. This necessitated two sprays for the first brood and two sprays for the second brood in addition to the calyx spray.

2. There was found to be a variation of as much as a week in the spray dates for different localities in the valley, depending on the type of soil and the lay of the ground.

3. There was a variation in spray dates for different orchards dependent on the type of culture given. In general, anything growing near the tree trunk tended to delay and prolong the transformation of the moth.

4. No appreciable destruction of the over-wintering larvae by the cold winter temperatures was apparent. Birds, ants and spiders were observed to have destroyed a small percentage of over-wintering larvae.

5. There was an overlapping of the first and second broods brought about by the prolongation of the first brood.

6. The bulk of the eggs of the first brood of moths were found to be deposited on the fruit itself, only about twenty per cent being located on leaves.

7. The data collected indicated that the calyx spray is important in the control of the insect, but does not have all the value that has been credited to it.

8. From the observations and experiments it is evident that five sprays are advisable in a season like 1920 in the Payette Valley; one calyx spray, two sprays for the first brood and two sprays for the second brood.

9. The observations indicate that in certain years the spraying fails to adequately control the codlin moth for the following reasons:

(1) In years of very short crops little or no spraying is conducted, and the number of wintering-over larvae increase greatly causing a heavy infestation the following season.

(2) In many sections there are not enough spray outfits to adequately spray the orchards on time.

(3) There is much careless spraying. Not enough liquid is applied to cover all sides of the fruit with poison.

(4) Many growers have not been putting the poison on the trees at the times when it would do most good, that is, they have not kept informed of the stages of the codlin moth and have applied the spray in a hit and miss manner; if they had known how the insect was developing the spray would have been more effective.