PRELIMINARY REPORT ON THE LIFE HISTORY OF THE CODLING MOTH AND SPRAYING EXPERIMENTS AGAINST IT

By E. Dwight Sanderson, *Durham, N. H.*

For the past three years we have been working on the life history of the codling moth in New Hampshire, and making experiments to determine the value of spraying at different times. The greater part of the life history work was done by Dr. T. J. Headlee or was under his immediate charge, as was also much of the field work.

It is convenient to commence the consideration of the life history of an insect with a discussion of its wintering habits and then follow it thru the season. Seven large apple trees were thoroly examined by a competent student last spring to determine the position in which the codling moth larvæ hibernate and their mortality. An average of 55 cocoons per tree were found, 70% being on the trunk and 30% on the limbs. Records showing the height of the cocoons on the trunk indicate clearly that more cocoons are to be found just below the crotch and just above the base of the tree, than are to be found midway on the trunk. It seems very evident that the larvæ descend from the limbs to the trunk and ascend from the dropped apples on the ground to the lower part of the trunk to form their cocoons. Eighty-seven per cent were killed by birds, 4% by fungus disease, 3% by cold, and but 5% remained alive. An examination of numerous other trees in the same orchard including the cocoons of 1,086 larvæ showed that 66% had been killed by birds, 9% by cold, 6% by fungus and 19% were alive. The percentage of mortality will of course vary with local conditions, but previous experience reinforces these observations that only a very small percentage survive hibernation.

In the spring a short tube is spun out from the cocoon prior to pupation. In 1906 the average date of pupation for 43 larvæ was May 25, the average length of the pupation stage 20 days, the majority of adults appearing about June 14. In 1907 the average date of pupation for 103 larvæ was June 16, the average length of the pupal stage being 16 days and the majority of adults appearing about July 2. It is interesting to note the difference of four days in the pupal stage in the two seasons. We have not studied the temperature data with sufficient care to determine whether the difference is due to temperature, but such a result shows the necessity for having a large series of individuals upon which to base our conclusions as to the life history of an insect, and also the importance of studying it for several years if its economic importance warrants it. The length of the pupal stage varied from 3 to 64 days, those pupating earliest in the spring remaining the longest in that stage.

In 1906 the first moth appeared June 9 and in 1907 on June 13. In 1906 the last moth appeared June 26 and in 1907 on July 8. Thus there was a period of emergence of 17 days in 1906 and of 25 days in 1907. It is interesting to note the relation of these dates of emergence to the time of blooming of the apple. In 1906 the first moth appeared about ten days and the majority about 15 days after the petals dropped. In 1907 the first moth appeared about the time the petals dropped and the majority a little over two weeks later. Thus in 1907 the earliest eggs deposited would have hatched about ten days after the first spraying, while in 1906 they would not have hatched until three weeks after the first spraying. This will have an important bearing upon the effectiveness of the spray applied to the foliage and would possibly make it more effective one year than another.

Oviposition goes on for about a month, a female laying from 20 to 70 eggs, the average being about 50. The eggs we have observed hatched in 9 or 10 days. It is exceedingly difficult to get the female to oviposit. In 1906 we secured the record of seven moths, but in 1907 we were utterly unable to secure any oviposition tho the same methods were pursued. The eggs are laid on the upper or under surface of the leaves, only a fraction of 1% being laid on the fruit in this locality. An examination of about 700 eggs in the orchard shows that they are on the upper or under side of the leaves, but that on some varieties there are a large number on the upper side and on others more on the under surface. The average distance of 588 eggs from the nearest apples on three trees in 1907 was 6¼ inches, while the average distance from the nearest apples of 744 eggs on six trees during the past two years was nine inches, the average distance of eggs on each tree varying from 2 inches to 28 inches. Eggs are sometimes laid several feet from an apple and indeed are quite commonly laid upon trees with no fruit at all. An examination of a young tree bearing no fruit showed 31 eggs. Apples which are wormy do not seem to be any nearer to eggs than those which are non-wormy. A careful record of the nearest egg to the apples on several trees showed that the eggs were as near to those non-wormy as to those wormy. Very frequently the egg nearest a wormy apple has been 12 inches distant.

The young larvæ feed on the under surface of the leaves mining into the mid ribs and angles of the veins branching from the mid rib and into the axils of the leaves. We have succeeded in rearing a larva in a water sprout and securing the moth from it and several larvæ lived for some time upon tender water sprouts altho we have no evidence that this occurs in nature. Feeding marks of the larvæ may, however, be readily found upon the foliage. It is evident therefore that the spray upon the foliage must affect the young larvæ. In 1906 eggs just ready to hatch were placed in the calices of apples and were bagged. Seven larvæ averaged 31.7 days in the apples. In 1907, similar experiments showed from 30 to 35 days spent in the apple, but the records were not as accurate. In 1906 no larvæ were observed to transform to pupæ and moths of the second brood during the summer, owing to the fact that the bands were not put on the trees earlier, but in 1907 pupæ were found under the bands, on August 8, the first moth emerging August 12 and moths continuing to emerge to August 23, in all 19 emerging, the most appearing on the former date. There was no increase in the number of larvæ under the bands at this time, but the number of larvæ found under the bands increases gradually from this time on. It is evident, therefore, that the first larvæ to mature transform to the second brood and it seems quite probable from a hasty study of the temperature records, that this is due to the fact that they are able to mature during the hottest part of the summer and that the later larvæ are not subject to so high temperatures. The number transforming and forming the second brood of moths is, however, exceedingly small, certainly not over 1% of the total.

We have been unable to secure very satisfactory data concerning the eggs of the second brood, but careful examination has failed to show them upon the apples. The second brood larvæ hibernate over winter and most of them can be readily detected by the small size and narrow head, but none of those partly grown transform in the spring. Whether a majority of the second brood mature in the fall is an open question. We have evidence that some of them undoubtedly do, but on the other hand we find a large number of the small hibernating larvæ which fail to transform in the spring.

In 1906 an elaborate spraying experiment conducted on 67 trees, there being 5 trees in each of 12 plots and 7 checks, practically failed to give any satisfactory results on account of the method in which the plots were laid out. The plots were arranged as shown in Fig. 3, the check trees being at one side of those sprayed. On either end of the sprayed plots were a few trees which had borne the previous year, but which were not in bearing in 1906. The Baldwin apple has a habit in New England of bearing every other year and all of the experiments here described were on Baldwins. As a result of the spraying, trees near those which had borne the previous year showed very much more injury by the first brood than those at the center of the sprayed plot more distant from them. As no barrier plot had been laid off

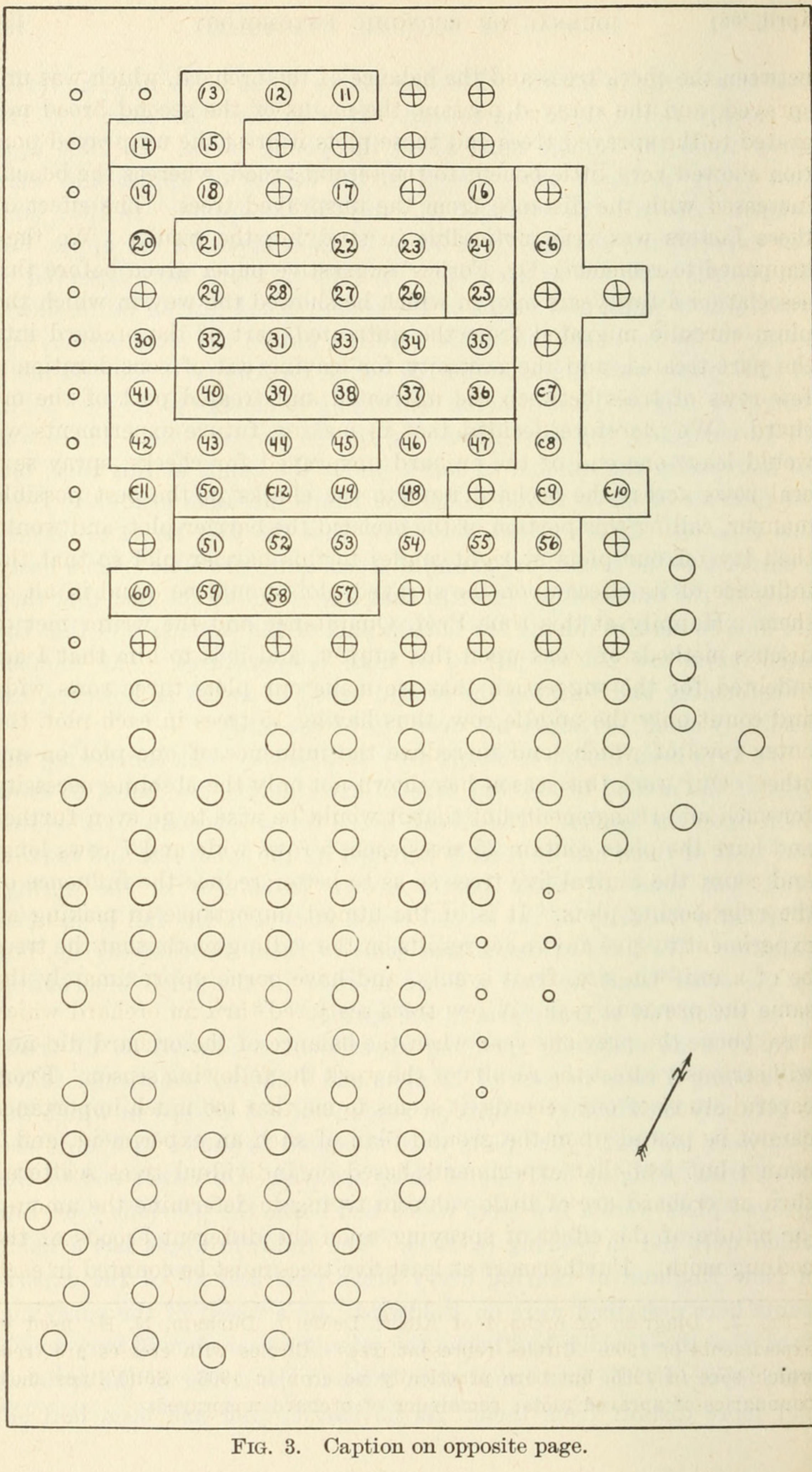

FIG. 3. Caption on opposite page.

between the check trees and the balance of the orchard, which was unsprayed, and the sprayed portion, the moths of the second brood migrated to the sprayed trees and those plots nearest the unsprayed portion showed very little benefit to the second brood, whereas the benefit increased with the distance from the unsprayed trees. The effect of these factors was very noticeable in studying the results. We then happened to remember Dr. Forbes' suggestive paper given before this association a few years ago, in which he showed the way in which the plum curculio migrated from the untreated part of the orchard into the part treated, and the necessity for leaving out of consideration a few rows of trees between the untreated and treated part of the orchard. We therefore decided that in making future experiments we would leave one end of the orchard unsprayed for checks, spray several rows across the orchard next to the checks in the best possible manner, calling this portion of the orchard the barrier plot, and would then lay off our plots at right angles to this barrier plot so that the influence of its effect upon the sprayed plots would be equal in all of them. Happily at this time Prof. Quaintance and the writer met to discuss methods of work upon this subject, and it is to him that I am indebted for the suggestion that we make our plots three rows wide and count only the middle row, thus having 15 trees in each plot, the outer rows of which tend to reduce the influence of one plot on another. Our work this season has shown not only the absolute necessity for such an arrangement, but that it would be wise to go even further and have the plots contain 35 trees each, 5 rows wide and 7 rows long, and count the central five trees so as to better reduce the influence of the neighboring plots. It is of the utmost importance in making an experiment to give any exact results on the codling moth, that the trees be of a uniform size, fruit evenly, and have borne approximately the same the previous year. A few trees scattered thru an orchard which have borne the previous year when the balance of the orchard did not, will seriously affect the results of the work the following season. From careful study of our records, it seems to me that too much importance cannot be placed upon the ground plan of such an experiment, and I cannot but feel that experiments based on individual trees scattered thru an orchard are of little value in trying to determine the amount or nature of the effect of spraying upon the different broods of the codling moth. Furthermore at least five trees must be counted in each

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Fig. 3. Diagram of orchard of Albert DeMerit, Durham, N. H., used in experiments of 1906. Circles represent trees. Circles with crosses are trees which bore in 1905, but bore practically no crop in 1906. Solid lines show boundaries of sprayed plots; remainder of orchard unsprayed.

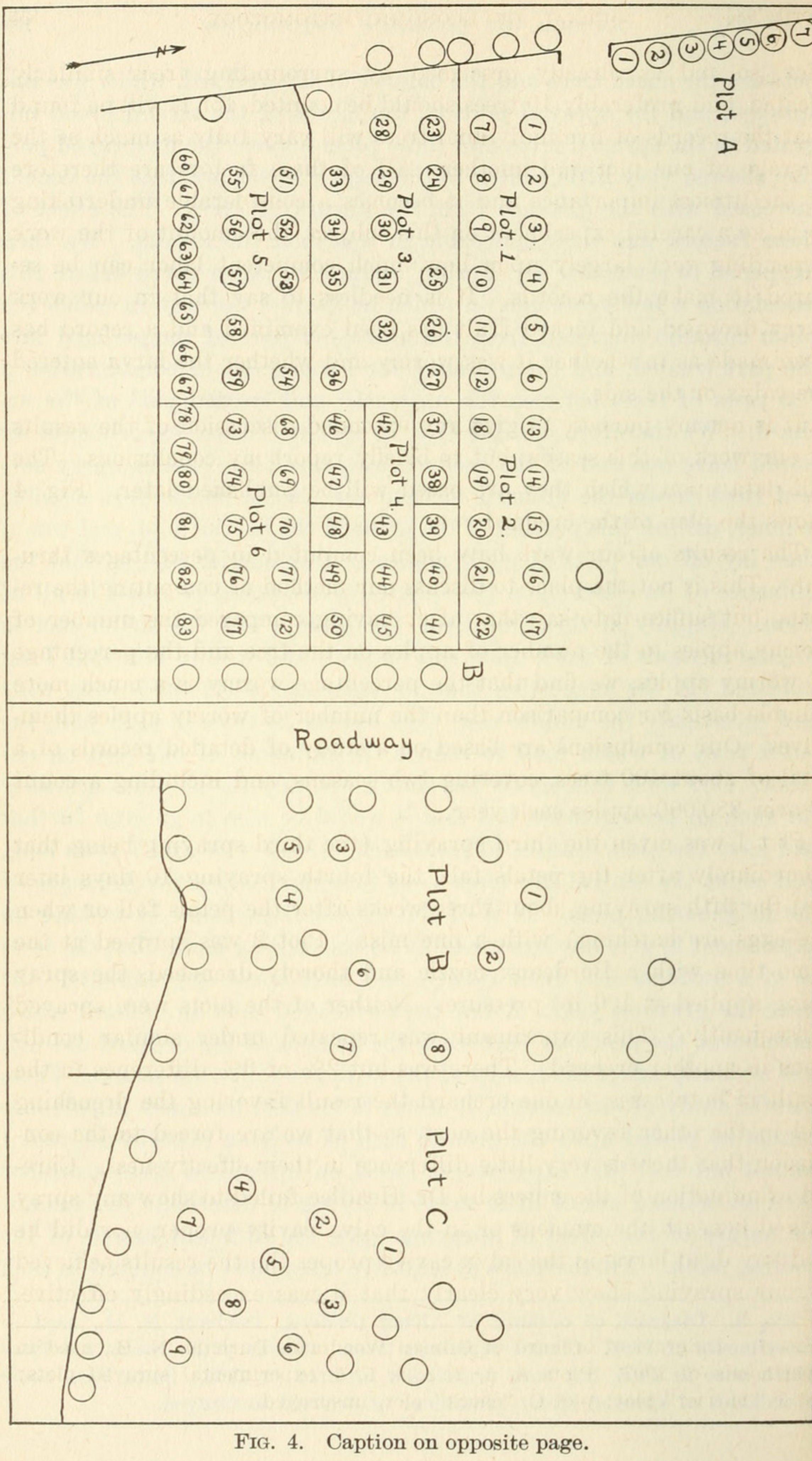

FIG. 4. Caption on opposite page.

plot isolated as already described by surrounding trees similarly treated, and preferably 10 trees should be counted, for it will be found that the records of five individual trees will vary fully as much as the average of one plot and another. All of these factors are therefore of the utmost importance and it becomes a considerable undertaking to make a careful experiment on this subject, the amount of the work depending very largely upon how much competent labor can be secured to make the records. It is needless to say that in our work every dropped and picked fruit has been examined and a record has been made as to whether it was wormy and whether the larva entered the calyx or the side.

It is not my purpose to give any extended discussion of the results of our work of this season, but to briefly report my conclusions. The full data upon which they are based will be published later. Fig. 4 shows the plan of the orchard.

The results of our work have been computed in percentages thruout. This is not the place to discuss our method of computing the results, but suffice it to say that after having compared the number of wormy apples to the number of apples on the tree and the percentage of wormy apples, we find that the percentage wormy is a much more reliable basis for comparison than the number of wormy apples themselves. Our conclusions are based on a study of detailed records of a total of about 400 trees, covering two seasons, and including a count of over 350,000 apples each year.

Plot 1 was given the third spraying (the third spraying being that immediately after the petals fall, the fourth spraying 10 days later and the fifth spraying about three weeks after the petals fall or when the eggs are hatching) with a fine mist. Plot 2 was sprayed at the same time with a Bordeaux nozzle and thoroly drenched, the spray being applied at 100 ℔. pressure. Neither of the plots were sprayed subsequently. This experiment was repeated under similar conditions in another orchard. There was but 2% or 3% difference in the result in both cases, in one orchard the result favoring the drenching and in the other favoring the mist, so that we are forced to the conclusion that there is very little difference in their effectiveness. Careful examination of the calices by Dr. Headlee failed to show any spray lodged beneath the stamens or in the calyx cavity proper, nor did he find any dead larvæ in the calyx cavity proper tho the results achieved by our spraying show very clearly that it was exceedingly effective.

FIG. 4. Diagram of orchard of Gilman Woodman, Durham, N. H., used in experiments of 1907. Plots A, 1, 2, 3, 4, 5, 6, experimental sprayed plots; plot 3, "barrier" plot; plot C, "check" plot, unsprayed.

We are therefore led to doubt whether in New England it is necessary to wait until the stamens have withered in order to force the spray beneath the stamens into the calyx cavity proper, as suggested by Dr. Ball last year.

Plots sprayed with paris green, one-third pound to the barrel and arsenate of lead, two pounds to the barrel, the insecticide being used with Bordeaux mixture, showed practically no difference in their effect. The addition of Bordeaux to arsenate of lead seems to decrease its value very little if any. The arsenate of lead and paris green have now been compared for two years, and where a sufficient amount of either is used, so that the percentage of arsenic is the same, one seems to be about as effective as the other.

The proportion of the larvæ entering the calyx has always been a matter of interest, as bearing directly upon the effectiveness of spraying into the calyx. We find for the first brood that the percentage of larvæ entering the calyx on unsprayed trees varies from 67% to 77%, in four orchards averaging 73%. For the second brood at Durham the proportion was 67% and 78% on unsprayed trees, averaging 74.5%, or practically the same as for the first brood, but at Pittsfield and Deerfield, back from the coast, and on hills, the second brood is smaller, as will be shown later, and but 22% to 24.6% of the second brood enter the calyx on unsprayed trees.

We have endeavored this year to determine the exact effect of the spray upon the larvæ, as to whether they are killed in the calyx, on the foliage, or on the surface of the apple, for both the first and second brood. Four trees were sprayed immediately after the blossoms fell with a hand atomizer, the spray being placed directly in the calyx without hitting the foliage. In all of these experiments the spray was arsenate of lead, two pounds to the barrel, without Bordeaux unless otherwise indicated. These four trees were not sprayed later. They gave a benefit of 59%, based on the percentage of the total fruit, which was wormy by the first brood, against a benefit of 91% on the plots which were sprayed in the ordinary manner so that the foliage was covered, indicating that about one-third of the benefit was due to the spray on the foliage.

One tree was not sprayed when the petals fell, but about three weeks later when the eggs were hatching. All of the apples on it were covered with paper bags and the tree was then thoroly sprayed, thus covering the foliage, but not the apples. The bags were then removed. It was contemplated to treat several trees in this manner, but as it was a week's labor to bag one tree, it was impossible. This spraying of the foliage gave only 18% benefit, based upon the percentage of the total fruit wormy by the first brood, with 10% benefit due to less injury by worms entering the side of the apple, and the balance of 8% due to benefit by fewer worms entering the calyx.

One plot was given the fifth spraying (that is three weeks after the petals dropped, or as the eggs were hatching) in the ordinary manner, in this the apples being sprayed as well as the foliage, but not having been previously sprayed, no poison was deposited in the calyx. This plot gave a benefit of 25%, based on the percentage of the total fruit wormy by the first brood, with a benefit of 15.7% due to fewer worms entering the calyx, and 9% due to fewer worms entering the side. If the benefit derived from spraying the foliage only upon the tree, which was bagged, be subtracted from that secured on the plot where both the foliage and apples were sprayed with the fifth spraying, we get the benefit due to the spray on the apples as regards the first brood, and find that it is about one-fourth of the value of this fifth spraying, and consists entirely of a benefit due to fewer worms entering the calyx or about 7%. If we divide the value of the fifth spray between the benefit derived from fewer worms entering the calyx and fewer worms entering the side, according to these proportions, we find that 9% out of the 25% is due to fewer worms entering the calyx and 15.7% due to fewer worms entering the side, or about two-fifths of the benefit is due to the calyx and three-fifths to the side.

But only 29% of wormy fruit are due to the work of the first brood on the unsprayed trees. When the benefit done by the control of the first brood alone is measured in terms of percentage of the benefit for the whole season, we find that only 27.5% out of 96% is due to the direct benefit on the first brood, where sprays III, IV and V were given. As a matter of fact the benefit of these sprayings thru their effect on the first brood is much greater than this and can only be shown after we have considered their effect on the second brood.

The addition of spray V did not seem to materially increase the benefit to the first brood when given after spray III, but the addition of spray IV and V to III show a very slight benefit over III and V.

In order to determine the true benefit of the effect of sprays on the first brood, we must find their effect on the second brood and by subtracting it from the total effect for the season we secure the real benefit due to the influence on the first brood, for it is evident that by reducing the numbers of the first brood there will be fewer of the second brood, and the apparent total benefit to the second brood is therefore really due to the effect of the lessened numbers due to the killing of the first brood, as well as to the direct effect of the spray upon the second brood.

The proportion of apples injured by the first and second brood varies with the locality and seemingly according to the percentage which transform to the second brood. Thus, at Durham in 1907, 29% of the wormy apples were injured by the first brood and 71% by the second, and in 1906 about 40% were injured by the first brood and about 60% by the second on unsprayed trees, while at Deerfield, 15 miles distant in the hills, in 1907, 70% were injured by the first brood and 30% by the second brood, and at Pittsfield, 30 miles distant, 48% were injured by the first brood and 52% by the second brood on unsprayed trees.

The effectiveness of the spraying seems to vary somewhat from season to season, and it seems quite possible that if heavy rains follow sprays III and IV that their effect upon the larvæ feeding upon the foliage would be lessened, whereas the benefit due to spray V would not be so much affected as if it is applied just as the eggs are hatching. Those plots sprayed with only the third spraying show but little total benefit to the second brood, averaging 12%, while those sprayed with the third and fifth sprayings show little or no total benefit, due probably to the fact that the destruction of the first brood was so complete that it is very difficult to determine any additional influence, unmistakably due to the effect of the spray on the second brood. But an addition of spray VI (spray VI being applied when the second brood of eggs are laid) gave 70% of the possible benefit due to the direct effect of the spray on the second brood. Spray IV gave a total of 22% of possible benefit, and spray V from 22% to 79% of possible benefit, with an average of 60% of the possible benefit due to the direct effect of the spray on the second brood, this being 22% benefit in terms of the benefit for the whole season, which was but 58%, or in other words 37% of the total benefit of the year was due to the direct effect of spray V upon the second brood.

Analyzing this benefit to the second brood, as to its effect upon the worms entering the calyx and side, we find that in the plot treated with spray III the benefit to the second brood was due entirely to those entering the calyx, giving 46% benefit to the calyx, but showing a loss of 14% or 15% in those entering the side, thus indicating that some of the spray lodged in the calyx affects the second brood which enter the calyx, but that the third spray has no effect on those entering the side, or in other words, kills very few or none of the second brood upon the foliage. When spray V or IV and V are added to spray III, from 75% to 80% benefit to the calyx is secured, but no benefit is secured to the side, but with the addition of spray V and VI (VI being applied for the second brood eggs), 95% benefit to the calyx and 25% benefit to the side for the second brood is secured, showing that spray VI kills mostly by its effect on larvæ feeding on the foliage. That no benefit is secured in lessening the number of worms of the second brood entering the side when spray V is added to spray III as would be expected from the additional spray put on the foliage, is doubtless due to the very effective work on the first brood of sprays III and V, leaving such a small percentage to be killed by the direct effect of the spray on the second brood as to be undemonstrable.

Spray V alone gave an average of 66% benefit thru lessening the worms of the second brood entering the calyx, and was the only one showing any benefit by lessening the worms of the second brood entering the side, giving 62% benefit to the side, the benefit to the side and calyx being practically equal tho twice as many worms entered the calyx as the side in the checks, thus showing that 66% of the second brood which entered the calyx are killed by spray on the foliage, as well as 62% of those which would enter the side. Thus about 60% of the benefit possible to secure from the direct effect of the spray upon the second brood is secured by the fifth spray alone applied to the foliage, and this spray would therefore be of importance in an orchard adjoining an unsprayed orchard near enough for the second brood of moths to spread to it. This is shown by our barrier plot, "B", which showed a total of 20% of the possible benefit due to direct effect on the second brood, while plot 3 surrounded by sprayed trees showed no such benefit. Furthermore the tree on which the apples were bagged and only the foliage sprayed with the fifth spraying, shows as much total benefit to the second brood as those in which the apples also were sprayed at the fifth spraying, again showing that most of the benefit due to the direct effect on the second brood is from the effect of the spray on the foliage.

Considering the part of the total benefit of the season which is due to the spray affecting the first brood as against the second brood, we find that in case of spray III, and III and V, that 88% to 100% of the total benefit was due to the effect on the first brood and thru it to the second brood, whereas in spray V only from 36% to 86% (average 64%) was due to the effect on the first brood, and from 14% to 64% of the total benefit was due to its effect on the second brood.

Thus in New England the first brood may be controlled by thoro spraying at the time the petals drop, spray III, but if there be danger of the second brood migrating into the orchard, spray V should always be added, as it will sufficiently control the second brood, tho if an infestation be serious in neighboring orchards, the sixth spraying will sometimes pay in addition. In New England the fifth spray should always be used with Bordeaux mixture for the control of the fruit spot irrespective of the codling moth, so that the addition of arsenate of lead will cost but little and will render the control of the codling moth much more certain. Early in August it is well to spray for the brown-tail moth and other leaf-eating caterpillars, which have been quite numerous in New England orchards for the last few years, and the sixth spraying will therefore control them and the second brood at the same time.

Considering the total benefits for the season, it is found that spraying the calyx only may give a benefit of 62%, while spraying the foliage only may benefit 52% (tho the influence of adjoining treated plots increased the benefit by decreasing the second brood of these plots, so that really the benefit is less), but where foliage and apples are sprayed at the fifth spraying, a benefit of 74% may sometimes be secured, tho here again neighboring plots have increased this apparent benefit.

Whether the spray on the foliage or the spray on the calyx kills the more larvæ, it is impossible to determine definitely from our results, which would seem to indicate that where spray V is given there are about two chances that a larva will be killed on the foliage to three that it will die in the calyx. Giving our figures as conservative an interpretation as possible, it would appear that of the total benefit for the whole season, at least one-third and possibly one-half is due to the spray on the foliage, and the balance to that deposited in the calyx. Heretofore only the spraying of the calyx has been emphasized, but in all cases where records have shown a separation of the apples wormy in the calyx and in the side, such as those given by Dr. Ball at our last meeting, a decided benefit has been shown by reducing the number of larvæ entering the side, and if this be due to the spray deposited on the foliage, how much of the apparent benefit from the decreased number of worms entering the calyx is really due to their being killed on the foliage?

Mr. Taft stated that in Michigan it is necessary to apply an extra spraying to control the second brood of this insect.

Mr. Fletcher asked if it is not probable that New Hampshire and Michigan are in two different faunal areas, as far as the codling moth is concerned.

Mr. Taylor was positive that the results given in this paper would not apply in Colorado. He recalled experiments and observations which had extended over fully five hundred acres of orchards where the first generation was practically controlled. Possibly the larvæ feed on the leaves to a greater extent in New Hampshire than in Colorado. In Grand Valley in Colorado in 1907, the entomologist kept track of the climatic conditions and the growers were notified by circulars, telephone or telegraph, so that the spraying was done at exactly the right time. The results that were secured in Colorado agreed in general with those of Dr. Ball in Utah.

Mr. Headlee stated that the apple crop was an absolute failure this year in Kansas and asked if there would be codling moths next year. In reply Mr. Quaintance said that the moth was supposed to have been exterminated in a small valley in California in this manner. Professor Garcia is now conducting an experiment of this kind in New Mexico.

Mr. J. B. Smith called attention to the fact that the pupae of Lepidopterous insects that are normally single brooded sometimes pass the winter in that stage. If this was occasionally the case with the codling moth, the species might be carried over in this way.

Mr. Taylor mentioned the entire absence of codling moth eggs in orchards that were barren in 1907, though badly infested in 1906, when a full crop of fruit was borne.

Mr. Fletcher remarked that he had once carried this insect over the second winter in the pupa form, but the specimen was kept in his office.

Mr. Quaintance presented the following paper:

NOTES ON THE LESSER APPLE WORM, ENARMONIA PRUNIVORA WALSH

By A. L. Quaintance, *Washington, D. C.*

(Withdrawn for publication elsewhere.)

Mr. Sanderson asked if the work of this insect can be distinguished from that of the codling moth larva. Mr. Quaintance replied that the larvæ work to a considerable extent in the calyx basin, boring holes into the flesh from one fourth to one-half an inch deep around the calyx and eating out the flesh under the skin in the calyx cavity; and also on the sides of the fruit, especially where touched by another apple or a leaf. Except as the fruit is nearly ripe, larvæ rarely penetrate to the seeds, as is done by the codling moth larvæ. The lesser apple worm, when full grown, is about the size of a half grown codling moth larva, but is somewhat fusiform in shape and is flesh-colored, or pinkish. On the caudal portion of the anal segment there is a small