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Michigan State University Agricultural Experiment Station
G.L. Ricks, W. Toenjes, Horticulture
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G. L. RICKS AND W. TOENJES

AGRICULTURAL EXPERIMENT STATION
MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

SECTION OF HORTICULTURE

East Lansing, Michigan

Success and Failure in Spraying for Scab and Codling Moth

G. L. RICKS AND W. TOENJES

It is a matter of common knowledge among commercial fruit growers living in the same district, growing the same varieties, having much the same kind of land, employing essentially the same cultural practices, using the same kinds of spray materials, and attempting to follow the same spraying schedule, that wide variations in the grade or quality of the product are present. These differences are indeed sometimes almost unbelievable. Thus, for example, Gaston¹ found that in the Fennville district, over a five-year period, certain growers produced 71 per cent A-grade apples while others in the same community produced just half that percentage of that grade. Gardner,² studying in somewhat greater detail the five-year records of a group of 100 representative apple growers of Western Michigan, reported some as producing upwards to 75 per cent while others produced less than 25 per cent of A-grade fruit.

Some of these variations were due to differences in size or coloration of fruit or in bruises occasioned by careless handling but many were due to differences in insect and disease control. Thus in 1924, 13 per cent of one Fennville grower's Baldwins were culled out because of scab while less than 1 per cent of his neighbor's Baldwins showed scab infection; in 1929, the corresponding figures for two commercial Baldwin growers of the same district were 58 and 3 and in both sets of instances the same spraying calendar was followed.

Exact data as to why these variations occur have been almost wholly lacking. Often those who have obtained poor control have been inclined to lay the blame on some supposed deterioration of the spray materials or to the weather or to an inadequacy of the spraying calendar, or perhaps to some other fancied reason while those who have obtained good control are equally uncertain as to just why their results have been so satisfactory while those of their neighbors have not.

Object

The object of the inquiry, upon which this is a report, has been to determine the relative importance of the several factors in orchard management that make for success or failure in the control of insects and diseases when essentially the same control program is used.

Procedure

In the early spring of 1929, representative commercial orchards, 17 in all, were selected in Allegan and Van Buren counties for detailed

¹Mich. Exp. Sta. Special Bulletin No. 160.

²Mich. Exp. Sta. Special Bulletin No. 161.

study. The size of trees and fertility of soil were comparatively uniform for the district, but central packing house grading records for preceding years showed that the culling required because of insect and disease injury varied greatly. General observations were made on the location of the orchards, the methods of soil management, the general condition of trees, pruning, distance of planting, and immediate surroundings. Notes were taken on the kind, capacity, and condition of the spraying outfits. Arrangements were then made with the owners to keep, throughout the season on specially prepared blanks, records showing the kinds and concentrations of spray materials that were used, dates of application, total gallons applied each day, and side of the trees covered. Each orchard was visited once during the application of each spray and observations were made as follows:— Time (as measured by a stop watch) required to spray an average tree, pressure used, methods of tree coverage, and thoroughness of coverage.

In 1930, the study was repeated in 12 of the original orchards and four new orchards were included. In 1931, two other orchards were included, making a total of 18 for that season.

SEASON	PERCENT
1929	22.77
1930	3.31
1931	2.17

Fig. 1.—Loss Due to Apple Scab by Seasons.

This figure presents an average of all Baldwin orchards studied. Scab attacks occur when weather conditions are favorable.

In each orchard, three average trees (yielding a total of 3,000 to 8,000 apples) of each variety were selected for the purpose of taking data on pest control. The trees were divided into top and bottom halves for the purpose of determining in what portion best control was secured. From each half of each of the trees selected, all fruits, including those that dropped, were carefully examined for injuries as follows: scab, stings, worms, russetting, aphids, and leaf-roller.

In the report that follows, no attempt is made to detail or even summarize all the data that were obtained; but, rather, there are presented or cited representative records that will serve to bring out the more significant lessons of the study.

Seasonal and Individual Differences in Scab Control

Scab, as all growers know, is easy to control in some seasons, while in others it is very difficult (See Fig. 1). This is due, mainly, to differences in weather. Conditions in the spring of 1929 were favorable to scab development and scab was unusually abundant in many or-

chards, but there were growers who suffered little loss from this disease even in that year. Figure 2 shows how marked the contrast was in the results of control methods used by several different growers. Since all these growers lived within a few miles of one another, their differences in control cannot be explained by weather conditions.

More or less obviously, the control of apple scab depends on the spray material used, its concentration, the time of application, and the thoroughness of coverage. With this in mind, try to determine why there was so wide a difference in control achieved by growers No. 11 and No. 3 (See Fig. 2), one of whom obtained excellent commercial

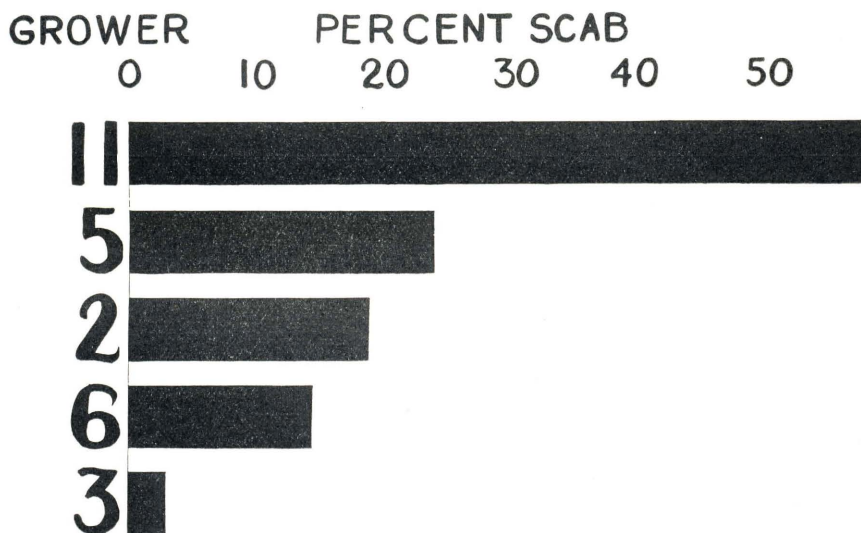


Fig. 2.—Loss Due to Apple Scab by Different Growers.

Variety is Baldwin. Certain growers suffer very little loss due to scab, while their neighbors are harvesting fruit which show over half scab. Why? The answer is incomplete coverage.

control and the other of whose efforts resulted in almost complete failure. Their orchards are located three miles apart in the Fennville district. A number of varieties are included in each orchard but Baldwin is the principal one. The trees in both orchards are at least 50 years old and range in height from 22 to 28 feet. The spraying outfits employed by these growers had been in use for a number of years. The one in orchard No. 11 had a rated delivery capacity of eight gallons per minute and maintained a pressure of 250 pounds. The one in orchard No. 3, had a rated capacity of 12 gallons per minute, was powered by a Model T Ford motor and maintained a pressure of 375 pounds. The material used by each grower was liquid lime-sulphur, at the concentration of $2\frac{1}{2}$ gallons per 100 gallons of spraying solution. Seventeen gallons of spraying solution per application were applied on the average tree by Grower No. 3 and only 12 by grower No. 11. Neither grower made a delayed dormant application. Table 1, gives the dates of the pre-pink, pink, petal-fall, and first cover

Table 1.—Time of application of spraying materials to orchards 11 and 3 in the 1929 season and scab control records.

Application	Grower No. 11	Grower No. 3
Pre-pink	April 15-16-19-24	April 15-19
Pink	May 6	May 3-7-8
Petal-fall	May 27-28-29-31	May 30—June 6-7
First cover	June 10-14-15	June 11-14
Control	Per cent Scab	
Total Crop	58.06	2.94
Top	68.56	5.05
Bottom	48.30	0.34
Drops	56.86	3.18

applications. It will be noted that all applications were made on practically the same dates.

Since the materials, concentration, and the times of application were essentially the same, there is only one other major factor, coverage, left that could account for the contrast. Field notes taken while the applications were being made in orchard No. 11, show that the center tops of the trees were not being well covered. Early infection occurred on the new leaves in that portion of the trees and, with dissemination of scab spores during every rainy period, new infections took place on the fruit and leaves in the lower parts of the trees. On the other hand, the owner of orchard No. 3, really had covered all of the exposed surfaces of his trees when he finished spraying.

Seasonal and Individual Differences in Codling Moth Control

Losses due to codling moth increased very rapidly in the Fennville district of Michigan during the three-year period covered by this study. This is brought out graphically in Figure 3. Taking 1929 as 100 per cent, the percentage of wormy apples in 1931 was 240 per cent. Presumably, this increase was due in large part to especially favorable weather conditions, for the fact that the increase in wormy apples was relatively less than the increase in stings indicates that on the whole the growers did a better job of spraying. For a given year, the ratio between stings and wormy apples represents the spraying efficiency. In 1929, there were almost as many wormy apples as apples having stings, but in 1931 the ratio was almost two to one indicating that the spraying efficiency had been increased.

A careful spray-man combating a heavy infestation of codling moths will secure a ratio of at least 10 stings to one wormy apple. It is possible with a moderately heavy population to secure a ratio of 30 to 1. In a general way, stings plus the wormy apples, represents the codling moth population. A harvested crop showing a high percentage of stings and low percentage of wormy apples indicates good spraying for that particular crop year but it also indicates that the spraying was faulty in the preceding seasons because the population had built up.

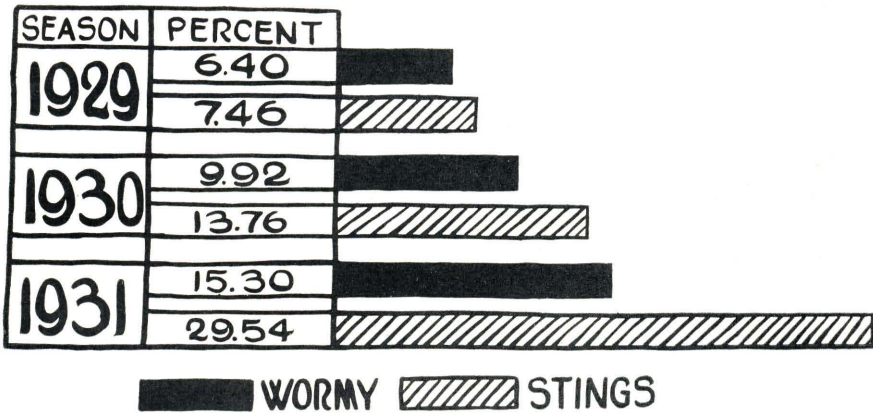


Fig. 3.—Loss Due to Codling Moth by Seasons.

This figure presents an average of all Baldwin orchards studied. The loss due to wormy fruit has increased 2½ times in two "worm" years.

If the spraying has been carefully performed, nearly all the worms will be killed and if this is carried on over a period of years, the population will be reduced to the minimum. Therefore, the most accurate measure of spraying for the control of codling moth is the per cent of wormy apples. However, though the losses due to codling moth increased rapidly in the district as a whole, some growers suffered much less than others. Certain ones held the insect in check. Figure 4 brings out the fact that some growers had no less than six times as many wormy apples as their neighbors, though they used the same spray materials on trees of the same varieties and of about the same size.

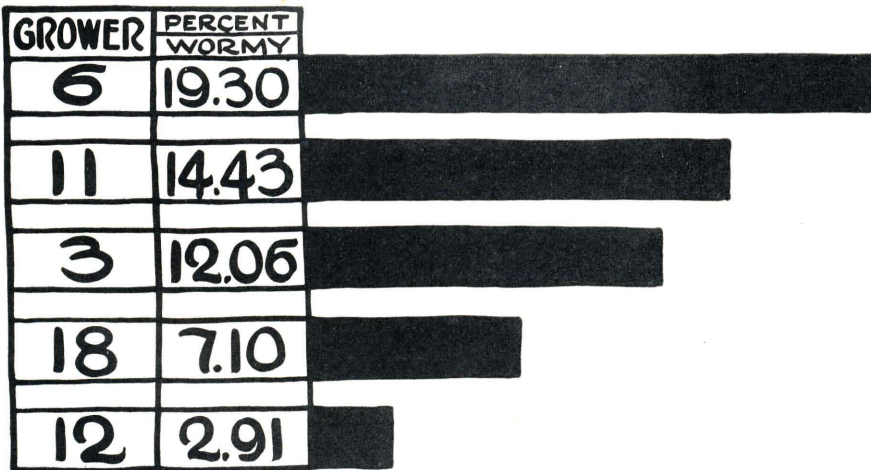


Fig. 4.—Loss Due to Wormy Apples by Different Growers.

Variety is Baldwin. Certain growers had six times more wormy fruit than their neighbors. The percentage of wormy apples was found to vary with the coverage secured.

Since determining the reasons for variation in control by different growers was one of the objects of this inquiry, the methods of a successful grower will be compared with those of one who more or less failed. The trees, which are at least 50 years old and 25 to 30 feet high, are in orchards located about two and one-half miles apart. Clean cultivation was practiced in both orchards. Grower No. 12, had an old spraying outfit with a rated delivery capacity of eight gallons per minute but it maintained 350 to 425 pounds pressure. Grower No. 6 had a newer spraying outfit with a rated delivery capacity of 15 gallons per minute, which was operated at 350 to 375 pounds but was able to maintain 450 pounds pressure. In both cases, lead arsenate was used at the rate of three pounds per 100 gallons of spraying solution, together with lime-sulphur for the purpose of scab control. Grower No. 12 applied 30 gallons of spraying solution, and Grower No. 6, 20 gallons on an average tree per application.

Table 2.—Spraying dates and codling moth control record for two orchards in the Fennville district, Michigan, in 1930 and 1931.

Application	1930		1931	
	Grower No. 12	Grower No. 6	Grower No. 12	Grower No. 6
Petal-fall.....	May 12-17	May 16-27	June 1-2-3-4	June 2-4-5
First cover.....	May 28—June 3	.....	.....	.....
Second cover.....	June 17-25	June 9-10-11	June 16-17-20-22	June 16-17-22-25-26
Third cover.....	July 14-17	June 27	June 29-30- July 1-2	July 3-6
Fourth cover....	July 29-Aug. 4	July 24-29	July 14-15-18-21- 22-23	Aug. 3-4-6-7
Fifth cover.....	Aug. 15-18	Aug. 15-16	Aug. 9-10-11-14- 17-21	Aug. 19-20
Control	Per cent Wormy			
Total Crop.....	0.54	13.57	2.91	19.30
Top.....	0.28	4.26	0.30	6.05
Bottom.....	0	1.55	0.08	3.13
Drops.....	2.19	36.14	18.67	54.00

Data on spraying dates and codling moth control for both growers and for the two years are presented in Table 2. Attention is called first to the fact that in 1930 grower No. 6, did not put on the first cover spray and neither grower No. 12 nor grower No. 6, made that application in 1931. Furthermore, there were slight differences in timing the other applications. It is impossible to assign to each contributing factor its share in the difference in worm control between the two orchards. Differences in timing the applications certainly did not seem to be mainly responsible, nor is the fact that the one orchard received one more early season cover spray of major importance. As in the case of orchards No. 11 and No. 3, just compared from the standpoint of scab control, the main difference seemed to be in the thoroughness of coverage of the top central portions of the trees,

field observations indicating that most of the "drops" came from those portions.

Table 3.—Control of apple scab in different parts of the trees.

(Figures indicate per cent scab.)

Variety	1929			1930			1931		
	Top	Bottom	Drops	Top	Bottom	Drops	Top	Bottom	Drops
Duchess.....	32.83	21.03	32.48	15.84	8.17	10.03	0.44	0.16	0.28
Wealthy.....	*	.....	.....	9.76	6.39	6.65	1.97	0.99	1.48
McIntosh.....	5.77	4.71	5.89	2.09	1.12	1.21	10.06	3.31	5.55
R. I. Greening	26.67	19.94	24.65	2.37	0.93	0.93	2.02	0.86	2.85
Jonathan.....	*	.....	.....	3.10	1.69	1.67	1.43	0.46	0.38
Baldwin.....	30.19	15.87	22.64	1.54	0.33	0.99	0.86	0.43	0.83
Average.....	23.87	15.39	21.42	5.80	3.11	3.56	2.80	1.04	1.90

NOTE.—This Table presents an average control of all growers and varieties studied. The McIntosh orchards varied in age from 18 to 20 years while orchards containing other varieties varied from 35 to 70 years.

*Records were not secured on these varieties for 1929.

That the problem of securing thorough coverage of the top central parts of trees, as illustrated by orchards 11 and 6, is representative of the entire district is borne out by the information presented in Table 3 and Figures 5 and 6. The differences between the several varieties are probably to be explained as being due to differences in the size of the trees, it being relatively easier to spray thoroughly the tops of low than it is the tops of high trees. It is common knowledge that McIntosh is more susceptible to scab than Baldwin but when the former variety is sprayed more thoroughly the loss may be less than for Baldwin (See Table 3).

Why Some Growers Succeed in Controlling Scab and Fail in Controlling Codling Moth

Some seasons that are favorable for the development of scab are unfavorable for the development of codling moth, others are not, and the reverse of these two conditions may be obtained. As already stated, the season of 1929 was favorable for scab development in the section where this study was made, while the seasons of 1930 and 1931 were especially favorable for codling moth but unfavorable for scab. It was noted that those growers who produce scabby apples during "scab" years, also produce wormy apples during "worm" years. However, growers who produce relatively scab-free apples in "scab" years may or may not produce worm-free apples in "worm" years. It is not difficult to understand why the grower who fails to control scab would also fail on worms, because he usually covers poorly the center tops of the trees, but, when he controls scab in an epidemic year and then fails to control codling moth, it is somewhat of a puzzle. The grower who controls scab is careful to cover the tops of the trees; therefore, the worms do not get his apples because of failure in that respect. This grower is likely, however, to use a mist or fog-like non-penetrating

spray. The most important scab applications are made at the pre-blossom and petal-fall periods when the foliage is very light and it is relatively easy to penetrate the full diameter of the trees. But worms make their attack when the trees are more or less fully clothed with their foliage so that a fog-like spray will not usually penetrate beyond the tree center, and thus the fruits are well covered only on the outward side, that portion of the surface nearest the outside periphery of the tree.



Fig. 5.—Location of Scabby Apples.

The average grower harvests the highest percentage of scabby fruit from the center tops of the trees; therefore, he should improve the coverage there.

Preliminary observations made in many orchards led to the belief that the codling moth worms were entering the apples principally from the inward side, on the side of the apple that is turned toward the center of the tree. In some orchards counts were made and the percentages of inward side entries determined. The observations were made by standing near the tree trunk and looking outward. The observer moved around the tree trunk and counted all the worm holes he could see on the lower half of the tree. Then he moved to the outside, generally within about six feet of the branches, and as he moved around the tree and looked toward the trunk, he counted all worm holes that could be seen. The plan was to count 500 wormy

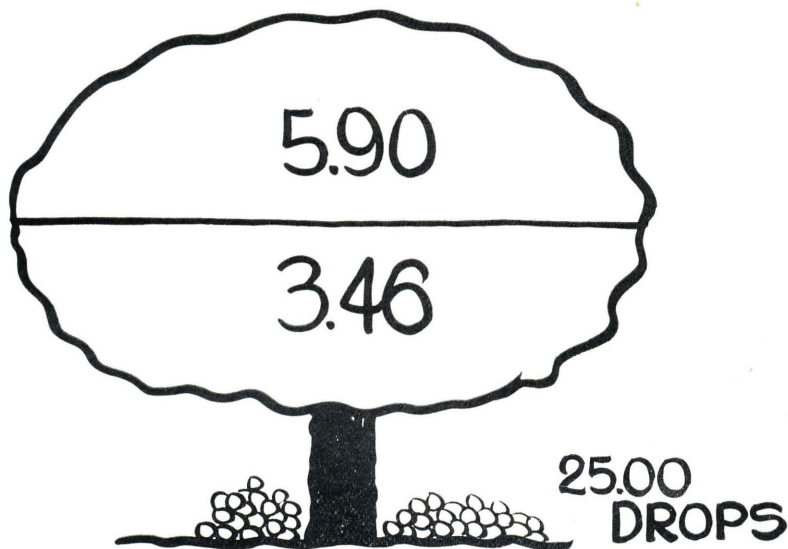


Fig. 6.—Wormy Apples in Top and Bottom of Trees.

This figure presents an average of all orchards and varieties studied in 1930 and 1931. Growers should improve the coverage in the top of the trees.

apples in each orchard. The results are presented in Table 4. It will be noted that almost two-thirds of the worms had entered from the inward side.

The owner of orchard No. 9, suggested that the wormy apples on three Northern Spy trees be picked and the location of worm entry recorded. The trees were 20 years old and had an average height of about 18 feet. All apples in which the worms had actually entered (not merely stung) and which could be reached from the top of an eight-foot step ladder were picked. Seventy per cent of the blemished apples were found to have been entered from the inward side (See Fig. 7).

The question then arose as to whether the worms prefer to enter

Table 4.—Location of worm entry into the fruit on sprayed trees.

(Incomplete Coverage)

Variety	Orchard No.	Per cent side* facing in	Per cent side facing out
McIntosh.....	7	61	39
McIntosh.....	15	64	36
McIntosh.....	9	70	30
Baldwin.....	6	64	36
Baldwin.....	17	60	40
Average.....		64	36

*Entering on the side of the apple that is turned toward the center of the tree. Determinations made before harvest time.

on the cool shady side of the apple. An unsprayed Jonathan tree was located and the wormy apples were picked from it in the same manner as from the Northern Spy trees. Three-fourths of the larvae had entered the apples from the outer side, the surface that faced the outside periphery of the tree (See Fig. 8). Perhaps this preference is associated with the fact that the outer side of the fruit is more exposed to sunlight. At any rate, the evidence is clear that the poorer control that some growers have over codling moth as compared with their control over scab is due to relatively poorer coverage of portions of the individual fruits with the later summer sprays.

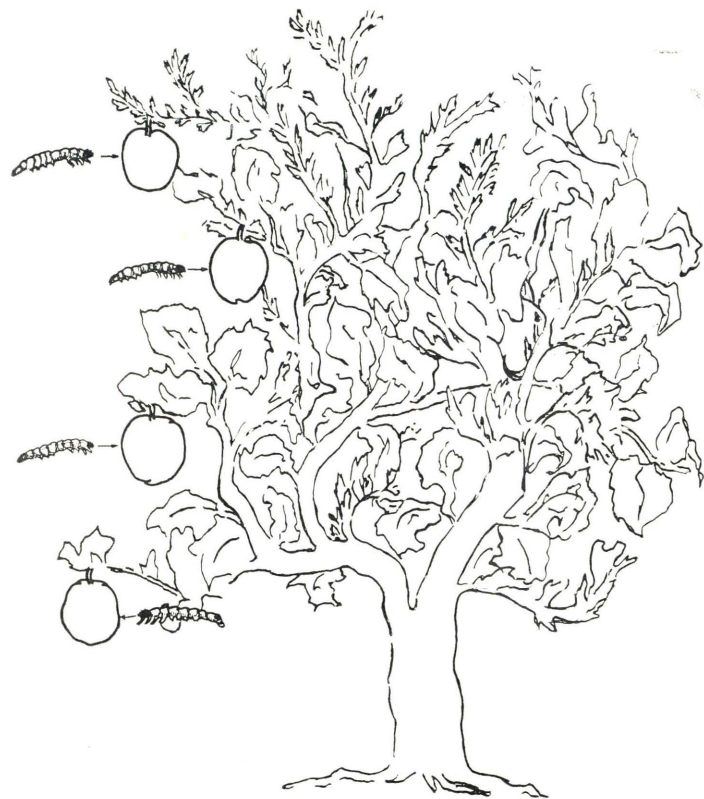


Fig. 7.—Location of Worm Entry on Sprayed Trees.

(Incomplete Coverage.) All apples in the crates are wormy. The fruit entered from the inner side filled four crates while only one and one-fourth crates were required for the outer side entries. The fruit was picked from the lower part of three 20-year-old Northern Spy trees.

The Relation of Spraying Equipment to Pest Control

In the orchards included in this study, many different types of spraying equipment were in use, ranging from 16-year-old two-cylinder small-capacity pumps mounted on 150-gallon tanks and powered by 4 h. p. one-cylinder engines to the most modern of high-powered large-capacity outfits (See Fig. 9). It was thought that a check on the work done by these different outfits would reveal great differences in their effectiveness in controlling pests. They were found to present a great range in efficiency, as measured by the time required to cover a given acreage or the ability to maintain high pressures or the amount of attention that they required for operation. On the other hand, no relationship was discovered between their age, size, capacity, or cost and the control of pests actually obtained from their use. Some of the oldest and smallest outfits, were doing some of the best work. Within the range of equipment presented by this study, far more depended on the operator than on the mechanical perfection or newness of his outfit.



Unsprayed



Sprayed (In)

Fig. 8.—Location of Worm Entry.

Larger numbers of worms enter apples on the outward-facing side. When only this side is covered, the inner-facing side. When both sides are covered practically all worms are killed.

Some observations were made which indicate that, in the purchase of new outfits, growers having commercial orchards of average size would do well to secure one with a rated capacity of at least 12 to 16 gallons per minute and capable of maintaining a pressure of at least 300 to 350 pounds.

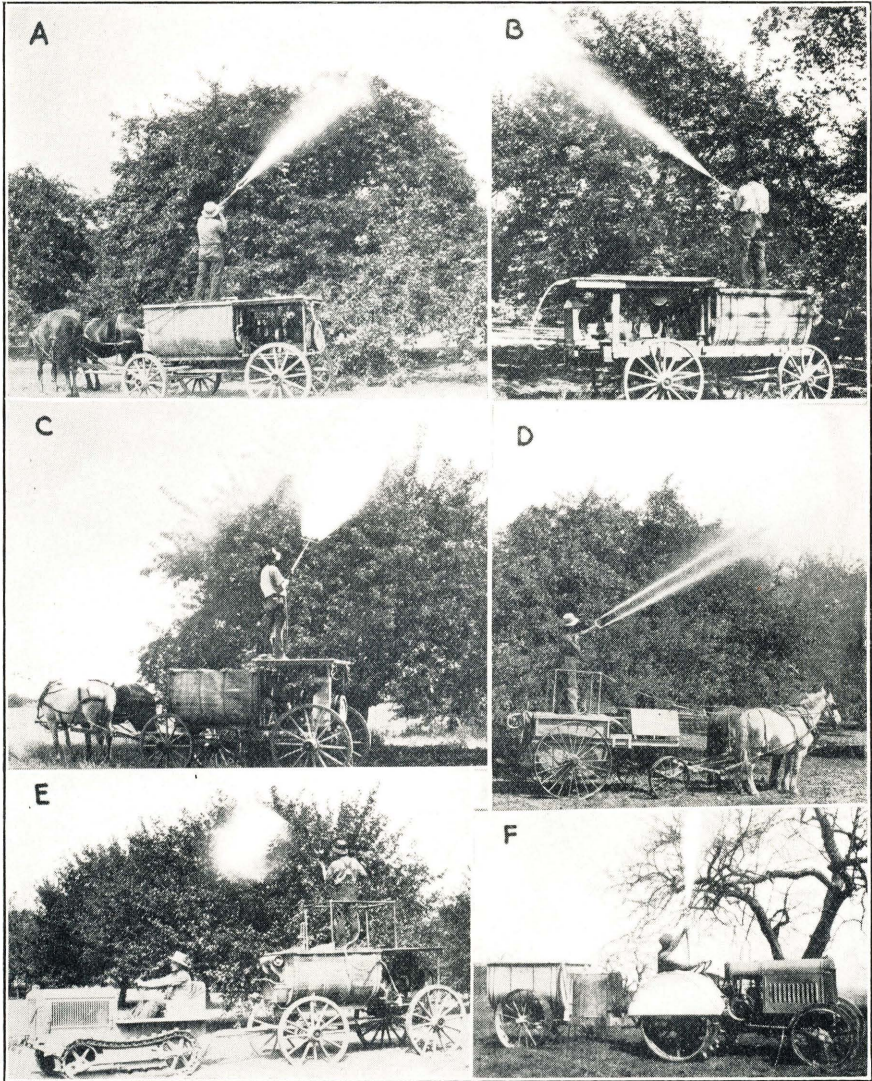


Fig. 9.—Types of Spraying Equipment Studied.

A—12 gallons per minute pump and 200 gallon tank; B—A home assembled outfit, 12 gallons per minute pump and 200 gallon tank; C—12 gallons per minute pump and 200 gallon tank; D—15 gallons per minute pump and 250 gallon tank; E—16 gallons per minute pump and 200 gallon tank; F—Power-take-off, 12 gallons per minute pump and 300 gallon tank.

General observations indicated that the single or double nozzle guns had more driving power than the multi-nozzle rods, which ranged from four to eight nozzles per rod. In general, the multi-nozzle rods gave good coverage in the early part of the season (scab season) on medium sized trees, but, when the trees were covered with heavy foliage, these multi-nozzle rods lacked the penetrating power to give the side of the apples which was toward the tree trunk sufficient protection against the codling moth worms. Of course, it is possible to prune small to medium sized trees heavy enough to permit coverage with the multi-nozzle rods, but such pruning will greatly reduce the bearing surface and this will decrease the yield so much that this procedure is not profitable. Due to lack of driving power, the center tops of **large** trees did not receive good coverage where the multi-nozzle rods were used in any application.

Crucial Tests for Codling Moth Control

In the course of the first two years' study, certain fairly definite opinions were formed as to the factors that are principally responsible for success or failure in the commercial control of scab and codling moth in western Michigan. It was decided, therefore, that in 1931, in addition to obtaining growers' records of the type secured in 1929 and 1930, certain experimental tests would be made that would put these opinions or hypotheses to a crucial test. Specifically, an answer was sought to the questions (1) how to obtain the best possible coverage while using only a reasonable amount of material, and (2) how effective such coverage is under conditions of extreme infestation as compared with the more usual incomplete coverage—though special effort (described later) was made to time the applications accurately.

The Orchards—Four orchards having poor control records were selected for the experiments. These orchards had a heavy scab infestation and a large codling moth population. For example, the apples harvested in orchard No. 11, showed 58 per cent scab in 1929, and in 1930, 42 per cent wormy; orchard No. 6, showed 14 per cent scab in 1929, and 13 per cent wormy in 1930; orchard No. 16, showed 20 per cent scab in 1930, and 22 per cent wormy the same year. Furthermore, good orchard sanitary measures had not been employed in any of these four orchards.

Orchards No. 11 and No. 17 adjoin, are similar in many ways, and will be discussed as a unit. The trees range in age from 55 to 70 years, in height from 25 to 30 feet, and in spread from 35 to 45 feet. They are rather dense with large over-hanging branches, some of which reach within 18 inches of the ground. The principal variety is Baldwin. Clean cultivation is practiced in the spring and a cover crop is sown in the late summer. Moderate quantities of nitrogen-carrying fertilizers have generally been applied each year. The spray outfits, operated by six h. p. engines, had a rated capacity of 15 gallons per minute. The operating pressure ranged from 300 to 350 pounds. All spraying was done with guns having a single nozzle.

Orchard No. 6 is of the Baldwin variety, about 60 years old. The trees range in height from 25 to 30 feet and in spread from 30 to 35 feet. The reason they have no greater spread is that they are too close

together, 33 x 33 feet. Many of the trees touch each other, though they have been kept fairly open by pruning. Clean cultivation is practiced. A spraying outfit with a rated capacity of 15 gallons per minute and operated with a 6 h. p. engine was used. The pressure ranged from 300 to 325 pounds. A gun having a single nozzle was used for spraying.

Orchard No. 16 is somewhat isolated, the nearest apple orchard being one-fourth mile away. There are a number of varieties in the orchard but the principal one is Baldwin. The trees are about 45 years old. They range in height from 20 to 27 feet and in spread from 25 to 35 feet. Clean cultivation is practiced in the early part of the season and a cover crop is usually sown in the late summer. A spraying outfit with a rated capacity of 12 gallons per minute and operated with a 6 h. p. engine was used. The outfit was in only fair condition, as the pump had been used 14 years and the engine six years. The pressure varied from 275 to 300 pounds. A gun and 4-nozzle rod was compared in this orchard. The gun used was of a standard type, single nozzle. The 4-nozzle rod (quad) used was of a standard type.

The procedure was to use the same spraying equipment and the same spray materials as had been used during the preceding two years. A block consisting of two rows running the full length of the orchard was selected, with the idea that there would be a drifting in of codling moths from adjoining rows. Records that are presented are limited to codling moth control because of the relatively small scab infection in 1931.

Materials Used—Standard spraying materials, as recommended in the Experiment Station Spraying Calendar for 1931, were used as follows: for scab, liquid lime-sulphur 2½ gallons to 100 gallons of spraying solution; for codling moth, lead arsenate 3 pounds to 100 gallons.

Timing the Applications for Codling Moths by Bait Pot Traps—The codling moth applications were timed according to the catch of moths in bait pot traps. The pot used was a 3-pint enamel kettle, covered with one-fourth inch mesh wire screen to keep out large insects. A rather stiff wire was run from the top of the bail to the rim of the kettle to prevent excessive tipping and to hold the wire screen in place. Eight pots were used in each orchard, suspended in the upper one-third of the trees by cord that was run through two one-half inch screw eyes to permit the pot to be lowered near the ground so that the moths might be removed and fresh bait added (See Fig. 10). To increase durability and ease of operation, the cord was dipped in hot paraffin. The moths were removed every day or every other day. When they were removed regularly, most of them were on the surface of the bait (See Fig. 10).

The bait used consisted of 2½ lbs. malt syrup, 1 lb. sugar, water to make 5 gallons, and ¼ cake of yeast per pot. The yeast was added after the bait was placed in the pot. The pot was filled about two-thirds full and fresh bait was added from time to time to replace that lost by evaporation. About every two weeks, the pots were washed with water and refilled with fresh bait, including the addition of ¼ cake of fresh yeast to each pot.

The spray applications were generally made three to seven days

after a "peak" catch of moths. When a big catch of moths was found in the pots, unhatched eggs were observed on the leaves and fruit. In the experimental plots of these orchards, sometimes as many as five eggs were found on the upper surface of one leaf. When high temper-



Fig. 10.—Moths on the Surface of the Bait.

Most of the moths will be found floating on the surface of the bait when they are removed regularly.

atures prevailed, the eggs hatched within a very few days. The plan was to have the apples completely covered with lead arsenate when the worms made their attack.

In reality, codling moth population and emergence varied greatly in the different orchards (See Fig. 11). The experimental block in orchard

No. 11 received a heavy side drift of summer brood moths from an adjoining orchard (No. 17). The experimental block in orchard No. 6 received a heavy drift of moths from both sides, as there was poor control of spring brood worms in the balance of the orchard. In orchard No. 16, the side drift of summer brood moths was light, as the balance of the orchard had had good commercial control of spring

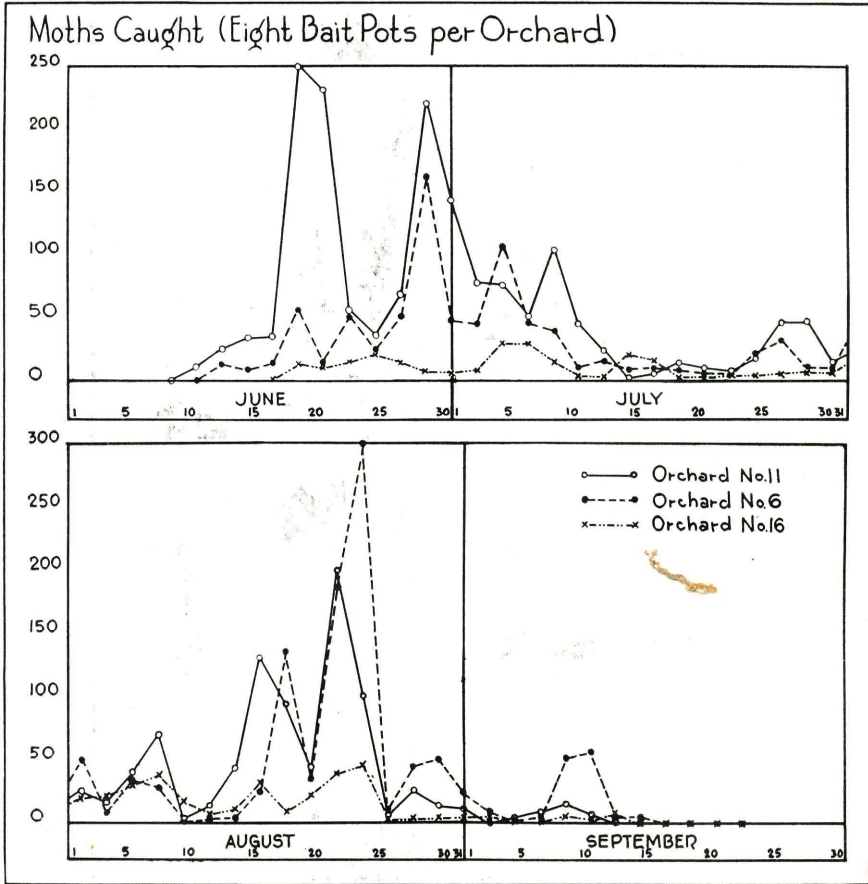


Fig. 11.—Variation of Codling Moth Population and Emergence.

The orchards are located within an area whose diameter is four miles. This figure illustrates the difficult task of making general recommendations. Therefore, if each grower desires specific information regarding the activity of codling moth in his own orchard, bait pots may be employed.

brood worms. In order to off-set the great exposure to moth infestation in orchards No. 6 and No. 11, more spray applications were considered necessary.

Methods of Application—Four different procedures or methods were used in these tests on completeness of coverage, as measured prin-

cipally by the control of codling moth. They may be classed rather arbitrarily as follows:

1. **Regular Tank Only**—In this method, the one in most common use in Michigan, all the spraying is done from the tank. Procedure consists in moving the spray gun up and down part of the time and

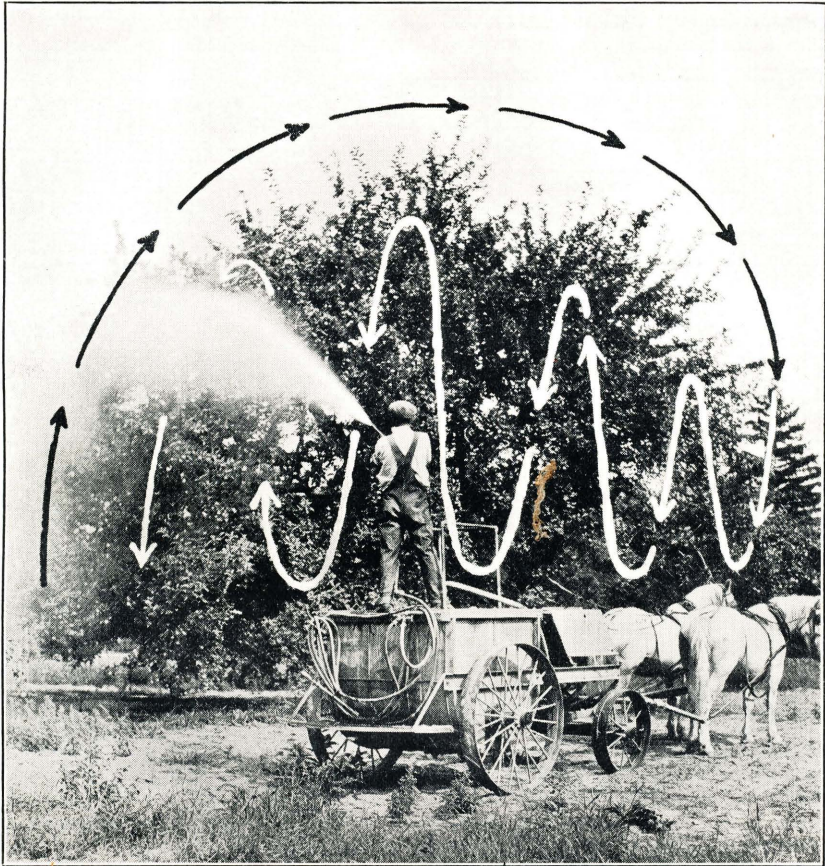


Fig. 12.—The "Improved Tank Only" Method of Covering Trees.

First stop. The spray rig is stopped opposite a point mid-way between the tree just completed and the tree which the operator is starting to spray. The operator covers the outer portions of the tree first, with a pencil stream as indicated by the black arrows. The stream is then changed to a long cone and the remainder of the tree is covered by moving the stream as indicated by the white arrows.

back and forth horizontally part of the time. Usually, the cone of spray is moved rather rapidly over the center tops of the trees and no **special** effort is made to drive the material clear through to the opposite side of the tree; as a matter of fact, comparatively little penetrates beyond the center.

2. **Improved Tank**—This method differs from the preceding one only in that the operator is careful to effect good penetration through the tree, covering the inward side surfaces of the fruits on the side of the tree opposite from which the spraying is being done, and likewise to effect complete coverage of foliage and fruit in the center top portion of the tree. It is recognized, of course, that no sharp line can be drawn between these two methods; and, in reality, the practices employed by individual fruit growers range between the two extremes. Their difference is in amount of care and degree of thoroughness rather than in kind. Nevertheless, the difference is great enough to warrant a few explanatory statements.

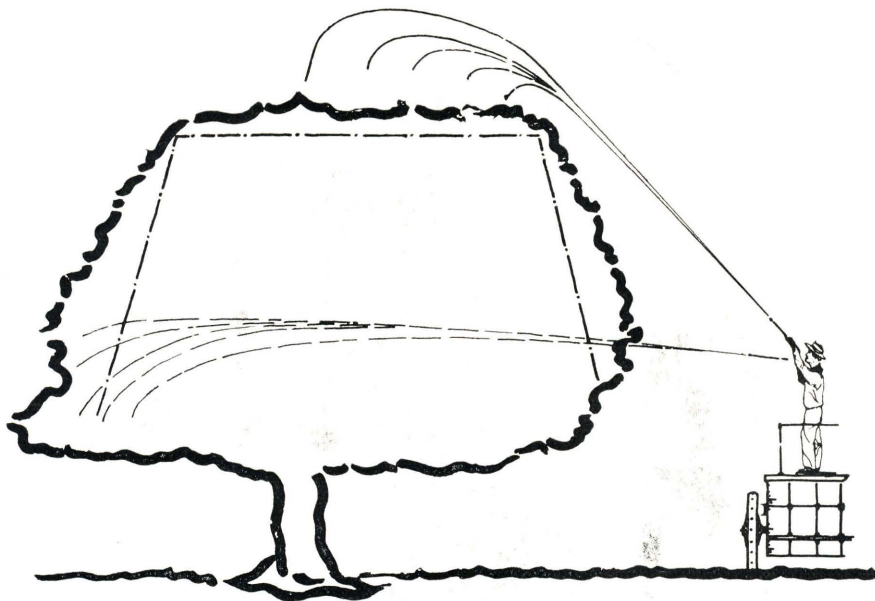


Fig. 13.—Second Stop “Improved Tank Only.” Side View.

The two most important procedures in securing thorough coverage are illustrated. Success in controlling apple scab and codling moth depends upon the sprayman's ability to cover the trees thoroughly.

In spraying large trees by the “Improved Tank” method, three stops are made per tree. The first is opposite a point about midway between the tree just completed and the one the operator is starting to spray. From this position, he “angles in” to cover the outermost parts with a pencil stream and the remaining portion to be covered from this stop with a long “cone stream,” moving the gun in an up and down direction (See Fig. 12).

The second stop is opposite the center of the tree. Again, the more distant visible portions of the tree are covered with a pencil stream or narrow cone, incidentally moving the stream **slowly** over the center top and directing it at a point **two to three feet above** the highest point to be covered (Fig. 13). The reason for aiming the stream higher than

the target is that in traversing the distance involved it "breaks" and falls enough actually to hit the target. If the stream is aimed directly at the highest part of the tree, it appears to the operator that the part is being covered, because it is hidden from view by the stream of spray material. However, on climbing large trees sprayed in this manner (i. e. aiming the stream directly at the top, instead of two or three feet above it), the observer repeatedly has found the center tops to be very poorly covered by rather small droplets. The reason for moving the



Fig. 14.—Second Stop "Improved Tank Only." Rear View.

The operator is directing the stream through a "hole" to secure penetration. The apples on the opposite half of the tree are being covered on the inward side. The tree has a spread of 40 feet.

stream **slowly** over the center tops of large trees is that these tops are generally more or less flattened and in reality comprise a relatively large portion (sometimes a third) of the bearing area. The remaining outside surface is then covered from this center position by moving the gun in an up and down direction and using a stream ranging from a narrow-long to a broad-short cone, depending on distance. Furthermore, from this center stop the **inward side** surfaces of the opposite or distant part of the tree are covered by means of a narrow cone or pencil stream directed through openings or "holes" between limbs (See Fig. 14).

The third step is made at a point beyond the tree and the procedure is similar to that at the first stop.

3. **Ground Only**—Most orchard spraying in the Pacific Northwest is done from the ground and the method is in limited use in Michigan apple orchards. It was regularly used by one of the growers included in this study. Details of procedure vary with different individuals employing this method. The writers' practice has been first to cover the inside surfaces of the tree, working from positions near the trunk, then to cover the outside. The gun was adjusted to throw a narrow or wide cone, depending on distance. Though special effort was made to cover thoroughly the center tops of the trees, it was found difficult to do this, even though a pressure of 300 to 350 pounds was maintained at all times.

4. **Tank and Ground**—In this method, two men did the spraying, one stood on the tank and gave his attention principally to the outside and center top portions of the tree. The other worked from the ground, paying special attention to the inside part of the tree.

Methods of Obtaining Control Data—To aid in studying the control

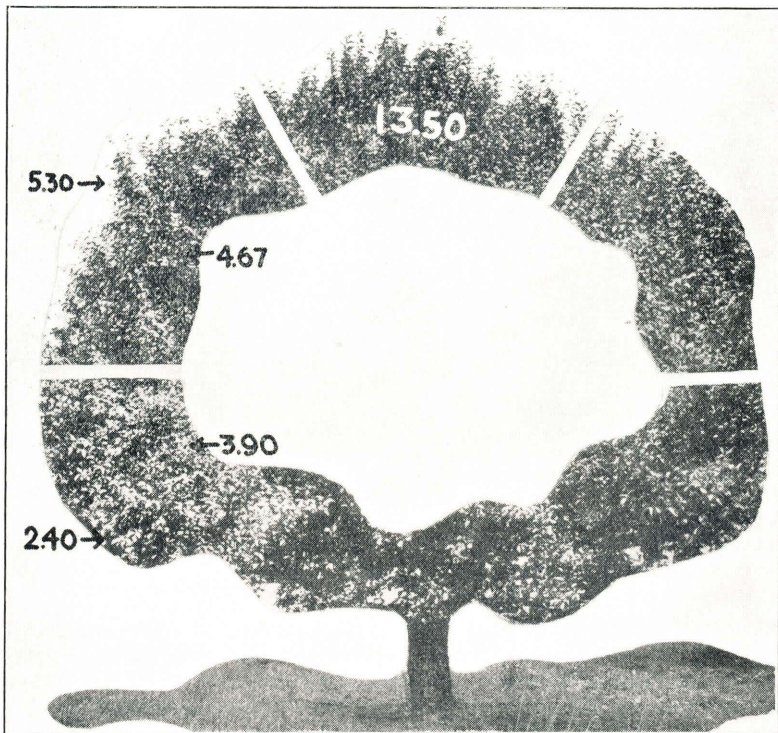


Fig. 15.—Control of Codling Moth by "Regular Tank Only" Method. Large Open Trees.

The kill of worms was fair on the outside bottom, but poor in the center top of the trees. The result of incomplete coverage is wormy apples. Compare with Figure 16.

under each treatment, the fruit from the experimental blocks was so harvested that codling moth infestation in one part of the tree could be compared with that in another part, as follows:

1. **Inside Bottom**—This included that part of the crop borne on the inner portion of the tree below a horizontal plane ranging, in different trees, from 10 to 12 feet from the ground.

2. **Outside Bottom**—This included that part of the crop borne on the outer portion of the tree below a horizontal plane ranging, in different trees, from 10 to 12 feet from the ground.

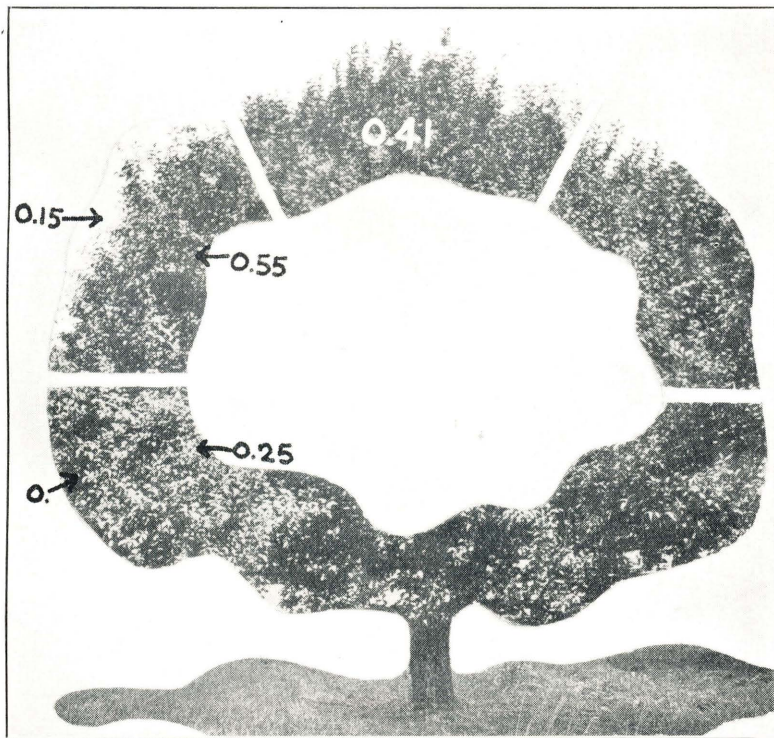


Fig. 16.—Control of Codling Moth by "Improved Tank Only" Method. Large Open Trees.

Less than $\frac{1}{2}$ of 1 per cent wormy apples were picked from any division of the trees. With good coverage nearly all the worms can be killed.

3. **Inside Top**—This included that part of the crop borne 10 to 22 feet from the ground and on the inside bearing surface.

4. **Outside Top**—This included that part of the crop borne 10 to 22 feet from the ground and on the outside bearing surface **except** for the center top.

5. **Center Top**—This included that part of the crop borne within an inverted cone and ranging in diameter from 8 to 12 feet and 20 to 28 feet from the ground.

Results—The effectiveness of the several methods of making spray applications that have just been described are presented diagrammatically in Figures 15, 16, 17, 18, and 21.

It will be noted that with the "Regular Tank" method of application (See Figs. 15 and 17) the percentage of wormy apples in the center tops of the trees was about five times that in the lower outside section. Control in both the lower and upper **inside** sections depended on the openness of the trees. Where they were thick and brushy, penetration of spray material was poor and control on the inner portion of the

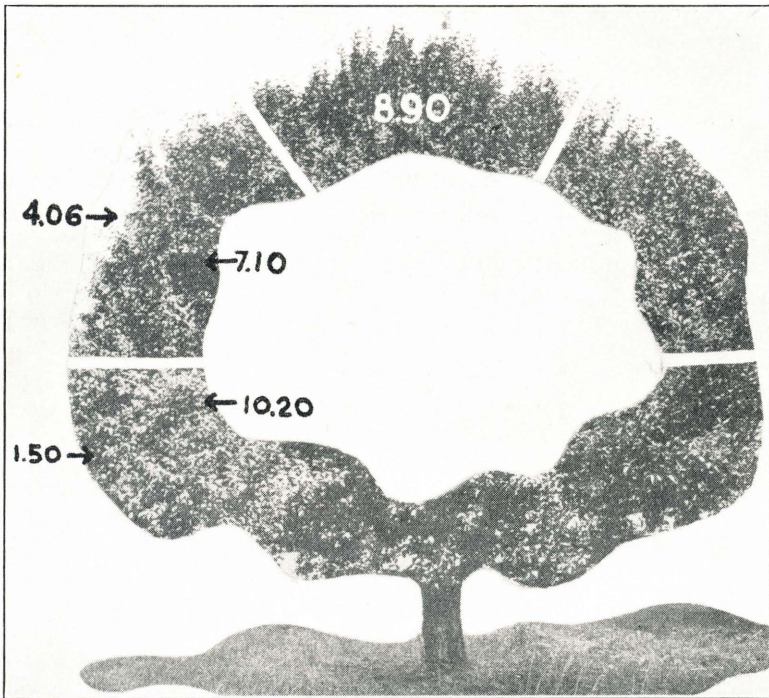


Fig. 17.—Control of Codling Moth by "Regular Tank Only." Large Dense Trees.

Almost seven times more worms entered the apples from the inward side (trunk outward) than from the outward side, on the bottom part of the trees. Due to poor penetration the fruit was not covered on the inward side.

tree correspondingly unsatisfactory. Moreover, the figures in the diagrams tell only a part of the story, for they are for the fruit that was picked at harvest time. These trees lost half of their crop by premature dropping and, by count, three-fourths of the drops were due to codling moth worms. It should be understood that these figures represent the operator's own control in orchards 6 and 17 included in this study.

Contrasted with these figures are those obtained by the "Improved Tank" method in orchard No. 6, one of the writers doing the spraying

but averaging only five to seven gallons more spray material per tree per application (See Fig. 16). In the top center of these trees, less than half of 1 per cent of the apples were wormy and the average for the remainder of the tree was less than a quarter of 1 per cent. Furthermore, the "drops" from these trees amounted to only 14 per cent of the crop and only 17 per cent of them were wormy.

The control obtained from the "Ground Only" method of application (See Fig. 21) was very satisfactory in all portions of the tree except the top center where it would be expected that coverage would

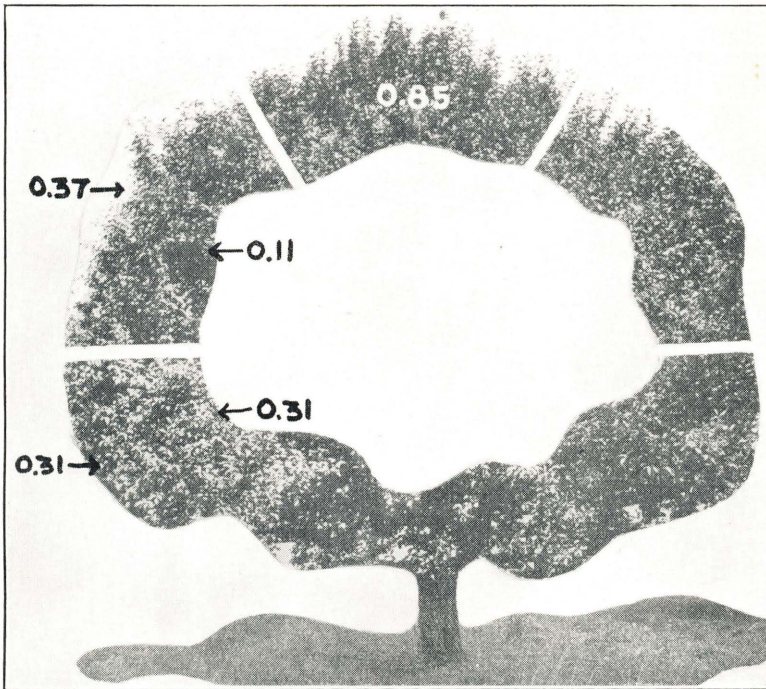


Fig. 18.—Control of Codling Moth by the "Tank and Ground" Method. Large Dense Trees.

Equal (0.31) per cent of worms entered from the inward side as from the outward side on the lower part of the trees. Compare with Figure 17. Where the moth infestation is unusually heavy most of the worms can be killed by thorough coverage.

be less complete. It is significant that the fruits on the inside portions of the tree were well protected. This method of application has much in its favor.

As might be expected, excellent results were obtained from the "Tank and Ground" method of application. There were 33 times as many apples entered by worms from the inner side, the surface facing the center of the tree, on the lower part of the trees sprayed by the "Regular Tank Only" as there were on corresponding portions of the "Tank and Ground" trees. This result is the more remarkable when

it is considered that the "Tank and Ground" block received a heavy side drift of summer brood moths from the adjoining "Regular Tank" block. One small bait trap hanging in this block caught 500 moths in the course of the season.

A Comparison of the Single Gun and 4-Nozzle Rod

One block running the full length of orchard No. 16 was sprayed all season with the single gun. Another block was sprayed all season with a 4-nozzle rod. The so-called "Improved Tank Only" was the

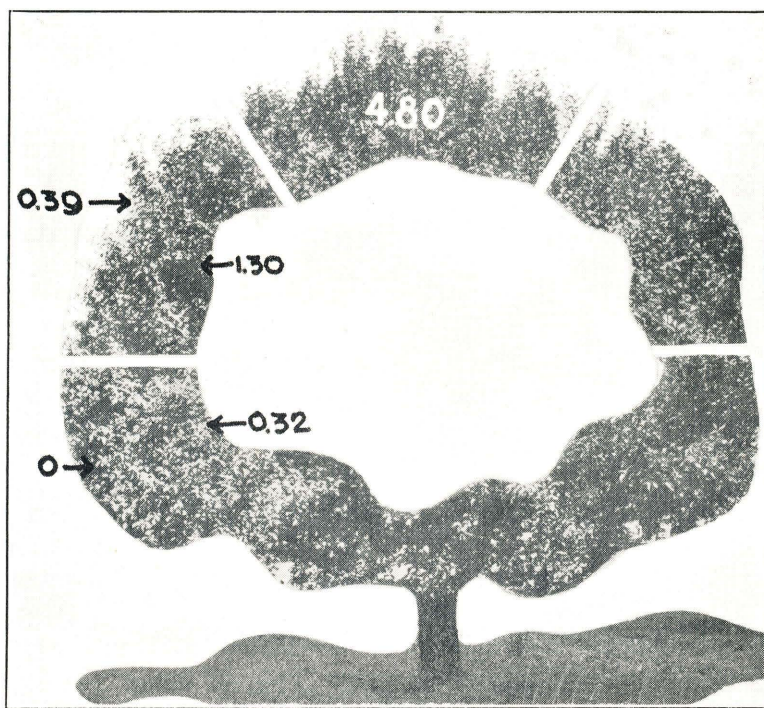


Fig. 19.—Control of Codling Moth by the 4-Nozzle Rod. Large Trees. The kill of worms was fairly good, except in the center top of the trees. Compare with Figure 20.

method of tree coverage used in both instances. Figures 19 and 20 show diagrammatically the control of codling moth worms in the two blocks. Fairly good control was secured in all parts of the trees except the center tops with the 4-nozzle rod. Almost 10 times as many wormy apples were picked from that part of the tree as from corresponding portions of those sprayed with the single gun. The 4-nozzle rod did not have the driving power to cover the center tops of the **large** trees.

Grower's Results from Changes in Spraying Methods

As already pointed out, in the average orchard in the Fennville district the loss due to worms was much greater in 1931, than in the preceding years (Fig. 3); nevertheless, certain growers were able materially to improve their control as compared with 1930. These growers timed their applications with the aid of bait pots operated in their **own** orchards and also changed their spraying methods to secure much better coverage than in 1930. An experimental block

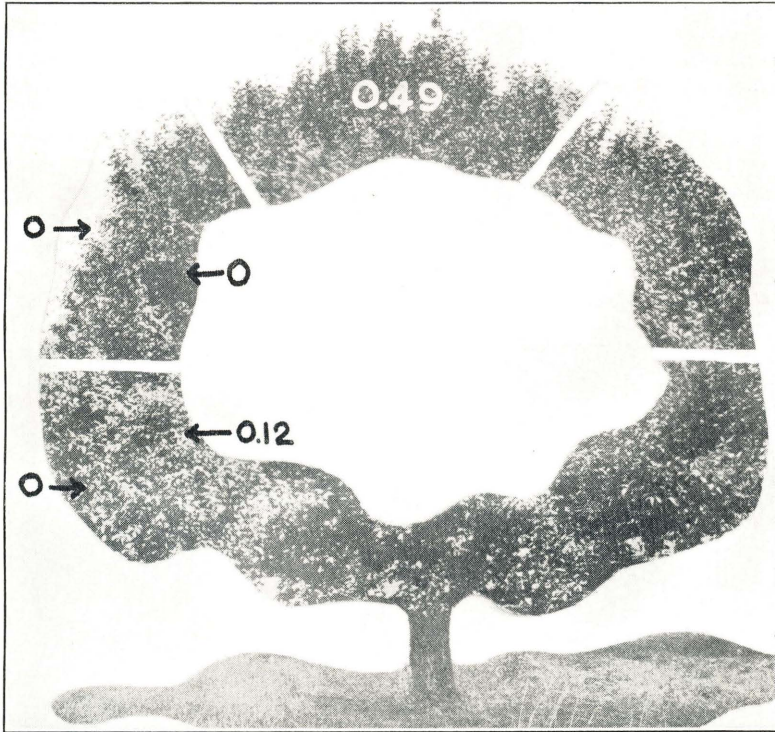


Fig. 20.—Control of Codling Moth by the Single Gun. Large Trees.

A good kill of worms was secured in all divisions of the trees. Due to its superior driving power, better coverage, especially in the center tops, was obtained with the single gun than the 4-nozzle rod.

was located in each of these orchards, but the experiment station workers were careful not to tell the growers when or how to spray, though the owners changes were due in part to watching methods employed in the experimental plots and in reality constituted growers' tests of the efficiency of improved methods of application. The improvement is shown in Table 5.

In 1931, Grower No. 16 did all the spraying from the tank with a single gun. His method of coverage was similar to that used on the experimental block (Improved Tank Only). Dates of applications were

Table 5.—Improvement in control of codling moth obtained by growers by better coverage and timing applications by bait pots.

	Grower No. 16		Grower No. 11	
	1930	1931	1930	1931
Picked apples.....	16.00*	3.90*	27.10*	6.10*
Drops.....	67.50	17.70	83.00	51.00
Total crop.....	22.20	6.50	42.00	25.00

*Figures indicate per cent wormy.

the same as for the experimental block. In 1930, part of the applications were made with a "quad," but even when the gun was used the coverage was incomplete. The time of application was governed by inclination of the grower and amount of general farm work to be done. Considering the picked apples only, in 1931 he reduced his loss due to worms to one-fourth of his 1930 figure and losses due to drops were reduced almost as much.

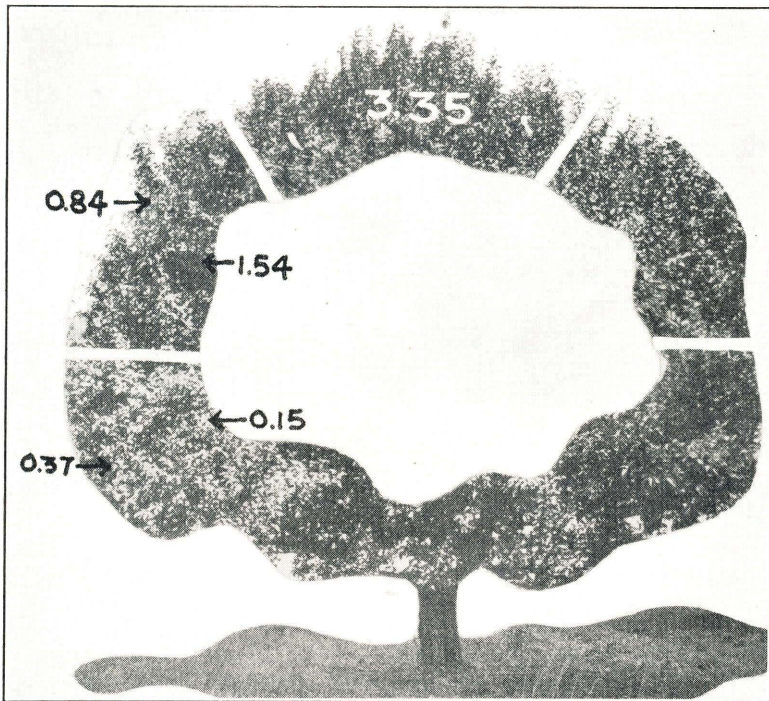


Fig. 21.—Control of Codling Moth by the "Ground Only" Method. Large Trees.

Note the contrast between the center top and the inside bottom.

In 1931, Grower No. 11, sprayed his large, rather dense trees from the "Tank and Ground." In 1930 the trees had been sprayed from the "Ground Only." He secured good coverage in 1931. He made the applications a few days after a "peak" catch of moths. He improved his control almost as much as Grower No. 16.

Individual Differences

In 1931, opportunity was afforded in Orchard No. 6 to compare the work of different operators. One block in this orchard was sprayed by two men using the "Tank and Ground" method. The adjoining block was sprayed by one man using the "Improved Tank Only" method. The same man that sprayed from the ground in the two-man block did all the spraying in the one-man block. Table 6 shows the difference in control of codling moth worms obtained under the two procedures.

Table 6.—Codling moth control records in the same orchard when the spraying was done by different men.

Tree Division	Per cent Wormy	
	Sprayed by one man	Sprayed by two men
Center top.....	0.41	3.31
Inside top.....	0.55	0.80
Outside top.....	0.15	0.85
Inside bottom.....	0.25	0.51
Outside bottom.....	0	0.25
Drops.....	17.54	28.06
Total crop.....	2.71	5.24

In the two-men block, there were over 13 times as many wormy apples picked from the center tops as from the outside bottom of the trees, and eight times as many as from the center tops of the one-man block. The differences cannot be attributed to differences in moth population because the bait pot traps actually showed heavier catches in the one-man block. In both blocks, most of the moths drifted in from the sides. The contrasts in control can be attributed only to difference in the coverage in the center tops, which could have resulted only from a difference in the thoroughness of the individual that applied the spray material.

A Crucial Test of Complete Coverage in Codling Moth Control

To determine the effect of one year's thorough spraying upon the codling moth population, one tree in orchard No. 6 in the block sprayed by the "Improved Tank Only" method and one in the "Regular Tank Only" block were scraped about one month after harvest time. The worms were counted and placed in vials (See Fig. 22). Where the apples on the tree had been kept covered throughout the season by spray mixture, only 11 worms were found under the bark of the tree.

Where the apples were not completely covered, 320 worms were found. Presumably, as large a proportion of the total that would live over and cause infestation the next season was recovered in the one case as in the other. It is easy to see how much more difficult would be the fight against codling moth in the second, than in the first of these blocks the following year. Furthermore, at harvest time, $20\frac{1}{2}$ bushels of apples were picked from the tree with only eleven worms under its bark and $16\frac{1}{2}$ bushels was the yield from the tree with 320 worms under its bark. The trees are of about the same size and the difference in yield was due principally to codling moth loss. For the whole season, the spray material cost 22 cents more per tree for complete coverage than for incomplete coverage.



Fig. 22.—Effect of Complete Coverage on Moth Population.

One month after harvest, 320 worms were removed from under the bark of one tree which had received an incomplete coverage of spray material. From one tree, which received complete coverage of lead arsenate, only 11 worms were removed.

Discussion

As the work upon which this is a report progressed, the conclusion toward which the results all pointed stood out more and more clearly: apple scab and codling moth control under Michigan conditions, though at times difficult, are both possible and practicable with the materials and methods now available. Furthermore, this control can be obtained with practically no additional cash outlay. It calls principally for greater care and thoroughness in the job of spraying, for that painstaking attention to details, to doing things just right, that is required in so many other lines of endeavor. In the parlance of the day, the grower must be "on his toes" in his job of spraying and nothing will compensate for failure in this respect.

There is no implication in these statements that improvements in spray materials or spray machinery or the spraying calendar are not desirable or that they will not come. They are desirable and undoubtedly they will come. In the meantime, however, the grower who makes the best possible use of present materials and methods, together with such supplementary sanitary measures as scraping and banding of tree trunks, need have no cause for dismay. This is the conclusion drawn from the results obtained by the fruit growers themselves and from a number of experimental tests conducted by the station investigators.

Acknowledgments

Grateful acknowledgment is made to the 23 apple growers of Allegan and Van Buren counties who furnished itemized records of their spraying. Without their fine cooperation, this report would not have been possible.

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SUMMARY

1. Certain commercial growers were found to suffer 19 times as great a loss due to scab and six times as great a loss due to wormy apples as their neighbors.

2. The marked contrast in control of scab and codling moth secured by different growers was found to vary principally with the thoroughness of coverage, rather than with differences in spraying schedule or in the materials used.

3. Growers may succeed against scab and fail against codling moth. The reason is that in the early part of the season the foliage is light and penetration of the full diameter of the trees easily accomplished, but, when the trees are heavily laden with leaves, special effort is required to drive the spray material beyond the tree trunk. If the spray material does not penetrate beyond the trunk, the apples are only covered on the outer side, next to the sprayer, and the worms enter from the inner side where the least amount of spray material is present.

4. In the average orchard, more scabby and wormy apples were picked from the top halves than from the bottom halves of the trees. The explanation is that the top portion of the trees was not properly covered with spray material.

5. The method of tree coverage in most common use and arbitrarily designated as "Regular Tank Only" **did not** give satisfactory kill of codling moth larvae in the center tops and inside bottoms of large trees. When **large open** trees were sprayed by the "Improved Tank Only" method the results were satisfactory. The "Tank and Ground" method gave good kill of larvae on **large dense** trees.

6. By thorough coverage, the codling moth population was greatly reduced in one season.

7. By better coverage and by timing their applications with the aid of bait pot traps certain growers in 1931 reduced their codling moth worm infestation to a quarter of its 1930 figure, in the face of a general increase in codling moth population in the district.

8. A single nozzle gun gave better control of codling moth on large trees than was obtained with a 4-nozzle rod.

9. Success in spraying depends more upon the individual operating the spray gun than any other single factor.