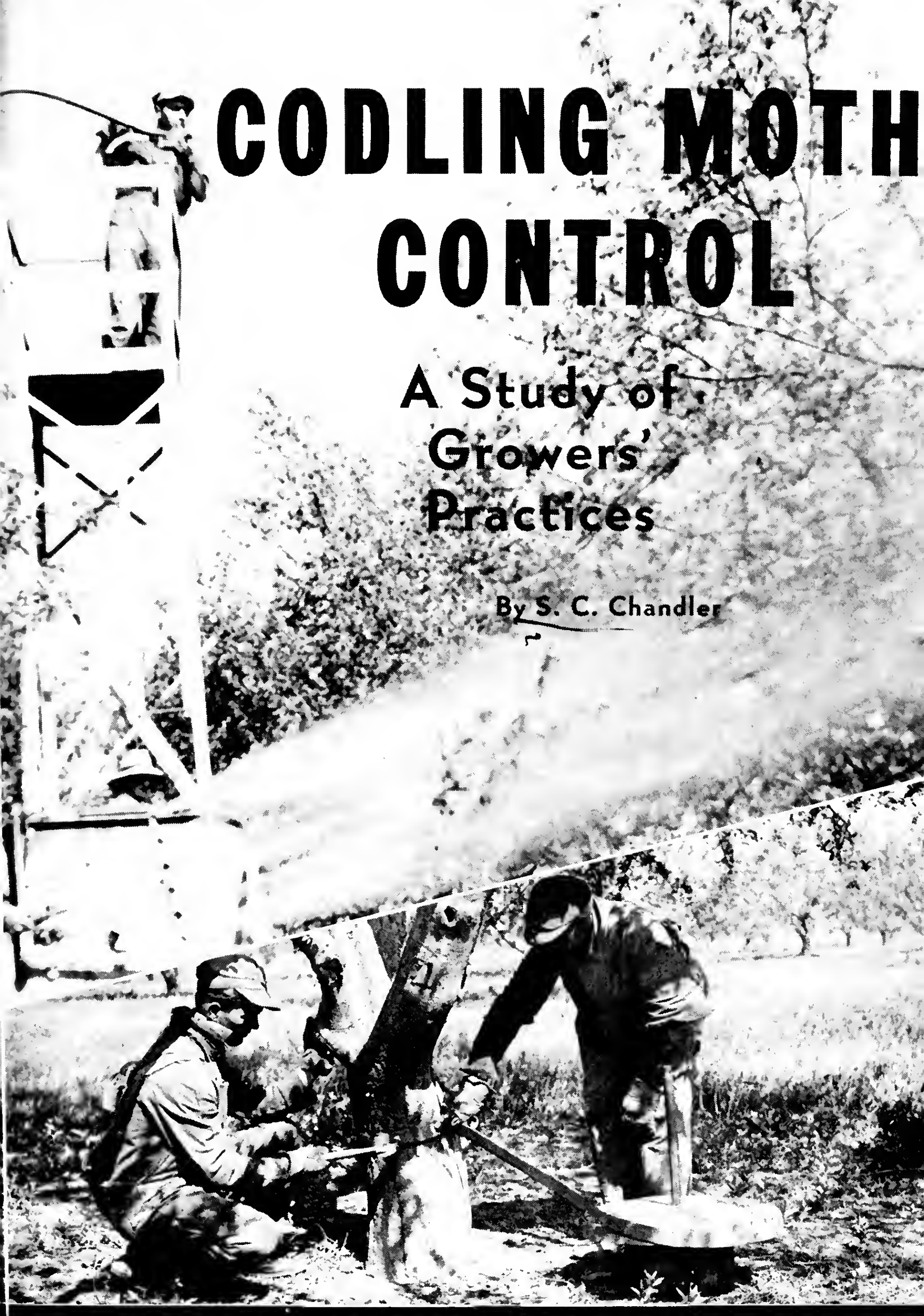
CODLING MOTH CONTROL

A Study of Growers' Practices

By S. C. Chandler



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CODLING MOTH CONTROL:

A Study of Growers' Practices

By S. C. Chandler, Field Entomologist,
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IN THE SOUTHERN apple-growing section of Illinois the control of codling moth, *Corpocapsa pomonella L.*, requires a specially heavy outlay of time and money. In fact, a grower's financial success may depend on his ability to hold the infestation down. That some growers generally secure control while others in the same neighborhood do not is common knowledge. The heavy infestation of 1941 and the losses it inflicted on some growers emphasized the difference between control and lack of it. As the season advanced, it became more and more clear that knowing why some growers succeed in getting control even in a bad year would be important and useful information to all apple growers. To this end, the survey reported herein was undertaken.

PLAN OF THE INVESTIGATION

Selection of orchards. The thirteen orchards under observation were all in the three-brooded area of southern Illinois, where codling moth control is normally more difficult than it is farther north. One was near Belleville, one near Centralia. The other eleven were about 40 miles north of Cairo in Union and Johnson counties.

Some of these orchards were selected for study because the growers usually or frequently had difficulty in securing codling moth control, or because in 1941 they had entirely failed to get satisfactory control. Others were chosen because the growers normally had good control, especially in the hot, dry season of 1941, when insecticides such as lead arsenate were less effective than usual.

Method of procedure. The purpose of the study was to determine what practices make for good codling moth control, what for poor control. The method of study depended on observation, on growers' methods and practices, and on records of infestation. Everything done in the orchard that might have a bearing on control was noted. No experiments were made unless the grower made them on his own initiative. No attempt was made to get him to change his spraying or management practices.

Only mature trees, usually at least twenty years old, were included in the study, and only certain blocks of trees were included in the intensive study of codling moth development and infestation. More than one variety was usually included. Where possible, one highly susceptible and one less susceptible to codling moth attack were chosen. The orchards ranged in size from 8 acres to nearly 200 acres. In large orchards representative blocks not exceeding 40 acres were chosen for sampling.

The orchards were visited about once a week during the growing season. Records of the spray schedule the grower used were kept. At the end of the first-brood period and again just before harvest, fruit in the tops and lower parts of the trees was examined, these trees being selected at random thruout the block. The examination could not include dropped fruit, but the degree of dropping was recorded. This method was considered accurate enough for the purpose.

Blocks of trees bearing a very light crop were not included in the survey for two reasons. First, a light crop will usually have a higher percentage of apples injured by codling moth than will a large or normal crop; this is especially true the year after a season of heavy infestation. Second, an unusually heavy spray program may be needed to protect a light crop, and the grower may not think the returns in sight justify the expense of carrying it out.

The lead analyses were made for the first two years by Dr. W. A. Ruth, Chief in Pomology, University of Illinois, and for the last year by a chemist of the Natural History Survey trained by Dr. Ruth.

AMOUNT OF INFESTATION JUST BEFORE HARVEST

The percentages of wormy and stung fruit in the tops and lower branches of the trees (Table 1) are based on the count made just before harvest.[1] They include all blocks under observation for the three years except a few experimental ones.

The count was made by blocks. Two hundred apples per block were taken from the tops and 500 from the lower branches.[2] This is about the proportion in which apples are borne on the different parts of the

[1] *Wormy* fruit is infested fruit; *stung* fruit is fruit that larvae have tried to enter but failed.

[2] The "total" percentages in Table 1 are figured directly from the number of wormy or stung apples in the total 700 apples examined. It would be an error to average the "top" percentage and the "bottom" percentage since those percentages are based on different-sized samples.

Table 1. — Final Codling Moth Infestation, 1942, 1943, 1944, Thirteen Illinois Orchards

(Percentage of infested apples found just before harvest: 200 apples examined in tops of trees, 500 in bottoms, in each block)

Variety and location on tree	1942			1943			1944		
	Wormy	Stung	Worm ratio[a]	Wormy	Stung	Worm ratio[a]	Wormy	Stung	Worm ratio[a]
Orchard 1									
Winesap									
Top	1.5	16.5	1.5	.5	1.5	2.5	1.5	5.5	1.5
Bottom	0	12.2	0	.2	1.4	1	1.0	7.4	1
Total	.4	13.1	...	.3	1.4	...	1.3	6.8	...
Starking Delicious									
Top	....	....	...	5.0	11.0	2.5	....	....	...
Bottom	....	....	...	2.0	10.0	1	....	....	...
Total	....	....	...	3.0	10.3	...	....	....	...
Orchard 2									
Starking Delicious									
Top	1.0	4.5	.5	2.0	8.5	.9	5.0	5.2	1
Bottom	1.8	.8	1	2.2	8.2	1	5.4	4.4	1
Total	1.5	1.8	...	2.1	8.3	...	5.3	4.7	...
York Imperial									
Top	2.0	11.0	2.0	3.0	10.0	3.7	2.5	3.0	4
Bottom	1.0	7.7	1	.8	7.0	1	.6	3.0	1
Total	1.2	8.4	...	1.4	7.8	...	1.1	3.0	...
Orchard 3									
Delicious									
Top	4.5	17.0	3.2	3.5	2.5	1.2	6.0	2.5	2.0
Bottom	1.4	10.4	1	2.2	3.2	1	3.0	1.6	1
Total	2.2	12.3	...	3.0	3.0	...	3.8	1.8	...
Winesap									
Top	7.0	36.0	7	4.0	4.5	4	9.8	9.8	16.3
Bottom	0	26.6	0	1.0	1.6	1	.6	4.4	1
Total	2.0	29.3	...	1.8	2.4	...	3.3	5.8	...
Orchard 4									
Golden Delicious									
Top	2.5	8.0	1.8	6.0	6.5	1.2	10.5	12.5	2.6
Bottom	1.4	3.2	1	4.8	7.0	1	4.0	8.6	1
Total	1.7	4.6	...	5.1	6.8	...	5.8	9.7	...
Winesap, Block 1									
Top	4.5	36.5	2.8	8.0	12.0	.9	12.0	14.0	2.5
Bottom	1.6	34.6	1	8.6	6.0	1	4.8	10.8	1
Total	2.3	35.1	...	8.4	7.7	...	6.8	10.3	...
Winesap, Block 2									
Top	1.0	29.5	.7	3.5	3.0	2.2	5.5	7.5	2.7
Bottom	1.4	28.2	1	1.6	3.4	1	2.0	6.0	1
Total	1.3	28.5	...	2.1	3.3	...	3.0	6.4	...
Orchard 5									
Delicious									
Top	17.0	32.0	2.3	....	....	...	....	....	...
Bottom	7.2	28.4	1	....	....	...	....	....	...
Total	10.0	29.4	...	....	....	...	....	....	...
Stayman Winesap									
Top	17.5	37.5	9.7	12.5	4.0	2.6	26.0	31.0	1.9
Bottom	1.8	32.0	1	4.8	4.2	1	13.8	28.2	1
Total	6.4	33.5	...	7.0	4.1	...	17.3	29.0	...
York Imperial									
Top	10.5	34.5	8.7	4.0	4.5	1.2	12.5	15.0	2.8
Bottom	1.2	30.4	1	3.2	6.2	1	4.4	16.4	1
Total	3.8	31.5	...	3.4	5.7	...	6.7	16.0	...

[a] Ratio of top infestation (wormy apples) to bottom infestation, counting bottom as 1.

(Table is continued on next page)

Table 1. — Codling Moth Infestation — Continued

Variety and location on tree	1942 Wormy	1942 Stung	1942 Worm ratio[a]	1943 Wormy	1943 Stung	1943 Worm ratio[a]	1944 Wormy	1944 Stung	1944 Worm ratio[a]
Orchard 6									
Delicious									
Top	6.0	51.0	2.4	39.0	21.0	1.9	14.0	20.0	1.5
Bottom	2.6	36.0	1	20.0	20.4	1	9.0	32.0	1
Total	3.5	40.3	...	25.4	20.5	...	10.4	28.6	...
Kinnard									
Top	7.0	46.0	1.6	19.5	24.5	1.6	7.4	22.0	3.1
Bottom	4.4	36.8	1	12.2	20.4	1	2.4	11.0	1
Total	5.1	39.4	...	14.3	21.0	...	3.7	14.3	...
Orchard 7									
Winesap, Block 1									
Top	7.0	45.5	2.7	8.0	65.0	2.7	10.0	12.0	4.5
Bottom	2.6	56.2	1	3.0	53.6	1	2.2	4.8	1
Total	3.8	53.1	...	4.4	56.8	...	4.4	6.8	...
Winesap, Block 2									
Top	11.5	81.5	2.4	14.0	50.0	2	52.0	22.5	1.5
Bottom	4.8	75.4	1	7.0	74.0	1	33.2	20.8	1
Total	6.7	77.1	...	9.0	67.1	...	38.5	21.3	...
Orchard 8									
Delicious									
Top	6.5	43.0	3.2	22.0	35.0	1.1	....	....	...
Bottom	2.0	32.0	1	20.0	35.4	1	....	....	...
Total	3.3	35.1	...	20.0	35.3	...	....	....	...
Winesap									
Top	3.0	45.5	15	9.0	27.5	3.7	45.0	44.0	4
Bottom	.2	17.8	1	2.4	18.4	1	11.2	76.0	1
Total	1.0	25.7	...	4.3	21.0	...	20.9	66.5	...
Orchard 9									
Golden Delicious									
Top	17.5	26.5	1.7	34.0	20.0	1.7	38.5	20.5	1.4
Bottom	10.2	24.6	1	20.0	24.0	1	26.6	26.0	1
Total	12.3	25.1	...	24.0	22.8	...	30.0	24.4	...
Winesap									
Top	10.5	45.5	1.1	16.0	17.0	1.6	29.5	26.0	2.2
Bottom	9.2	46.6	1	10.0	23.8	1	13.0	22.0	1
Total	9.6	46.3	...	11.7	21.8	...	17.7	23.1	...
Orchard 10									
Jonathan									
Top	84.0	16.0	1.2	7.0	6.0	3.2	23.0	11.0	2
Bottom	66.8	33.0	1	2.2	3.8	1	11.2	9.0	1
Total	71.7	28.1	...	3.5	4.4	...	14.5	9.6	...
Orchard 11									
Delicious									
Top	84.5	14.5	1.2	12.0	40.0	3.3	38.0	14.0	2.5
Bottom	69.0	26.0	1	3.6	42.0	1	15.0	23.0	1
Total	73.4	22.7	...	6.0	41.4	...	21.5	20.4	...
Winesap									
Top	....	....	...	14.0	10.0	11.6	28.0	15.0	4.6
Bottom	....	....	...	1.2	8.4	1	6.0	30.0	1
Total	....	....	...	4.8	8.8	...	12.3	25.5	...
Orchard 12									
Delicious, Block 1									
Top	29.5	42.5	1+	60.0	17.0	1+	97.0	3.0	1.1
Bottom	27.6	49.4	1	59.0	20.0	1	89.0	10.0	1
Total	28.1	49.4	...	59.3	19.1	...	91.0	8.0	...
Delicious, Block 2									
Top	66.0	21.5	1.2	60.0	26.6	—1	....	....	...
Bottom	55.0	33.0	1	61.8	27.0	1	....	....	...
Total	58.1	29.7	...	61.3	26.7	...	....	....	...

[a] Ratio of top infestation (wormy apples) to bottom infestation, counting bottom as 1.

(Table is concluded on next page)

Table 1. — Codling Moth Infestation — Concluded

Variety and location on tree	1942			1943			1944		
	Wormy	Stung	Worm ratio[a]	Wormy	Stung	Worm ratio[a]	Wormy	Stung	Worm ratio[a]
Orchard 12—Concluded									
Winesap									
Top	8.5	59.5	1.1	19.5	28.0	—1	67.9	30.5	1
Bottom	7.4	55.0	1	20.4	22.4	1	67.2	27.0	1
Total	7.7	56.3	...	20.1	24.0	...	67.7	28.0	...
Orchard 13									
Jonathan									
Top	52.0	33.0	.8	....	....	...	....	....	...
Bottom	60.0	23.0	1	....	....	...	....	....	...
Total	57.7	25.8	...	....	....	...	....	....	...
Winesap									
Top	....	....	...	20.5	16.0	1.2	80.0	10.0	1—
Bottom	....	....	...	18.2	13.6	1	85.0	12.0	1
Total	....	....	...	18.8	14.3	...	83.5	11.4	...

[a] Ratio of top infestation (wormy apples) to bottom infestation, counting bottom as 1.

tree. Rarely more than one-third of the apples are in the upper one-third of the tree. Apples from the lower branches were selected as evenly as possible over the block, care being taken to avoid trees in the neighborhood of such sources of infestation as packing sheds. Apples from the tops were usually taken from representative trees, 50 to a tree. The trees were so selected as to represent the geographical parts of the block.

Table 2. — Average Codling Moth Infestation, All Blocks, 1942, 1943, 1944 — Thirteen Illinois Orchards

(Percentage of infested apples found just before harvest: 200 apples examined in tops of trees, 500 in bottoms, in each block)

Orchard[a]	1942		1943		1944		Three years	
	Wormy	Stung	Wormy	Stung	Wormy	Stung	Wormy	Stung
1	.4	13.1	1.8	5.8	1.3	6.8	1.1	8.6
2	1.3	5.1	1.7	8.0	3.2	3.8	2.1	5.6
3	2.1	20.8	2.4	2.7	3.5	3.8	2.7	9.1
4	1.8	22.7	5.2	5.9	5.2	8.8	4.1	12.4
5	6.7	31.4	5.2	4.9	12.0	22.5	7.9	19.6
6	4.3	44.8	19.8	20.7	7.0	21.4	10.3	28.9
7	5.2	65.1	6.7	62.6	21.4	14.0	11.1	47.2
8	2.1	35.6	12.5	28.1	20.9	66.5	11.8	43.4
9	10.9	35.7	17.8	22.3	23.8	23.7	17.5	27.2
10	71.7	28.1	3.5	4.4	14.5	9.6	29.9	14.0
11	73.4	22.7	5.4	25.1	16.9	22.4	31.9	23.5
12	31.3	45.1	46.9	23.3	79.3	18.0	52.5	28.8
13	57.7	25.8	18.8	14.3	83.5	11.4	53.3	17.2

[a] The orchards are arranged according to degree of infestation, starting with those that had the lowest percentages of wormy apples as an average of all three years.

A condensed picture of codling moth control in these thirteen southern Illinois orchards for three seasons is given in Table 2. The final infestation counts made in all varieties, tops and bottoms, are combined for each orchard for each year and the three years' records averaged. The last season during this period, 1944, was probably for many growers the most difficult one in many a year.

Some of the orchards had a uniformly low infestation for all three seasons, some a uniformly high infestation. Others varied considerably from year to year and some from block to block. If Illinois growers knew all the reasons for these successes and failures, so that they could use the good practices and drop the poor ones, codling moth control over the state could be much simplified and the market grade of apples improved.

Susceptibility of Different Varieties

Of the varieties listed in Table 1, Starking Delicious, Delicious, Golden Delicious, and Stayman Winesap[1] when grown under similar conditions are likely to be more heavily infested than Winesap, Kinnard, and York. Between these two groups of varieties, the range in the *percentage* of wormy apples was smaller in orchards having a low infestation than in those having a high infestation (Table 1). In some cases the percentage of wormy fruit in susceptible and less-susceptible varieties was approximately the same.

Whether the differences between varieties were important or not to the grower depended, of course, on whether the infestation was high or low. For example, in Orchard 2 in 1943 about 1½ times as many Starking Delicious (2.1 percent) as York Imperials (1.4 percent) were wormy; but both infestations were so low that the difference was immaterial to the grower. In Orchard 6 in the same year the *ratio* of wormy Delicious to wormy Kinnard was roughly the same as that of Starking Delicious to York Imperial in Orchard 2 — about 1½ times — but the percentage infestations were so high (Delicious 25.4 percent; Kinnard 14.3 percent) that Delicious made a much poorer showing than Kinnard. From both varieties the grower's return was greatly reduced, and there was a heavy carryover of codling moth larvae to the next season. Other similar comparisons may be found in Table 1.

Thus if a grower manages to keep infestation very low, he need not be much concerned about variety.

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[1] Names of varieties follow the nomenclature in *Standardized Plant Names*, 2d edition, McFarland Company, Harrisburg, Pennsylvania, 1942.

Control Despite Unfavorable Weather

Cool, rainy weather prevailing in the spring of 1943 and 1944 tended to aid in control and to offset carryover[1] in some orchards, as shown by first-brood counts, some of which are given below.

	Final infestation	First-brood infestation
	perct.	*perct.*
	1942	**1943**
Orchard 10	71.7	.14
Orchard 12	31.3	1.3+
Orchard 13	57.7	1.3
	1943	**1944**
Orchard 6	19.8	.8

During the latter part of 1943 and 1944, especially in 1944, hot, dry weather resulted in a considerable increase in infestation. The increase in late-brood infestations in 1944 caused the heaviest carryover in years. In Orchards 5, 8, and 9, for instance, despite heavy spray programs, final infestations were 80, 26, and 47 times, respectively, what they had been early in the season, as the figures below show.

1944	First-brood infestation	Final infestation
	perct.	*perct.*
Orchard 5	.1	12.0
Orchard 8	.8	20.9
Orchard 9	.5	23.8

The increase in numbers may have been due partly to the fact that lead arsenate is less effective in dry weather and partly to other causes: more vigorous larvae, more eggs deposited, and lower death rate of larvae in a hot, dry season.

Yet growers who had systematically kept down the codling moth population in their orchards (Orchards 1 to 4, Table 2) got good control even in weather favorable for this insect.

[1] Larvae, or worms, that survive to provide the next year's infestation.

EFFECT OF WEATHER, SPRAYING, AND SANITATION ON CARRYOVER

Weather and Spraying Partly Offset Carryover

The number of larvae surviving the winter months has a definite influence on summer infestation. It may determine whether a grower must use few or many sprays to secure control.

Weather alone is not responsible for heavy carryover. Weather favorable to moth development may, of course, result in heavy carryover, as in 1943; but the low infestation in Orchards 1 to 4 (Tables 1 and 2) proved that weather conditions only partly explain carryover since the weather was essentially the same in all orchards.

Orchards 10, 11, and 13 demonstrate that weather and spraying schedules may partly offset carryover. These orchards had a heavy carryover from the season of 1942, as the large percentage of wormy fruit indicates; but in 1943 their infestation was greatly reduced (Tables 1 and 2). The low infestation was partly due to the effects of the wet spring of 1943 and partly due to the use of a very thoro spray program. In 1943 the average percentage of wormy apples in the 13 orchards at the end of the first-brood period was only .8 percent, whereas in 1942 it had been 4.1 percent.

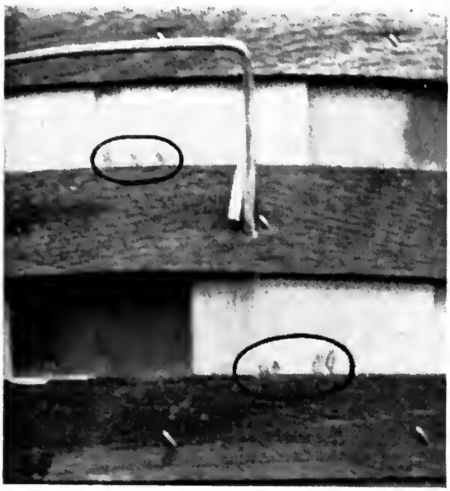
The belief of some growers and investigators that heavy infestation always follows heavy carryover is thus not supported by the experience of these growers. From the records of these orchards it is clear that heavy carryover from one season to the next *does not necessarily* mean that infestation will be heavy the second season.

Sanitation Appeared as Important as Spraying

By orchard sanitation is meant pruning to get rid of the places where codling moth larvae hide, burning brush, cleaning up trash, scraping, banding, screening sheds, and keeping crates free from infestation. One of the reasons for sanitation is to cut down carryover.

During this study, it was repeatedly noticed that good sanitary practices were counterbalanced by poor ones, and vice versa. For example, screening the packing shed is good orchard sanitation. Yet in Orchard 12, the only one in the survey having a screened shed. codling moth control was very poor. In Orchard 1, the cleanest in the study, every record was made near an open packing shed which should have been screened. The practices this grower followed, however, especially his adherence to certain sanitary practices, were so good that

A packing shed of this type can easily be made moth-tight. Here a little battening put over the cracks kept moths, hatched out on containers in the shed, from escaping to the orchard. Fig. 1



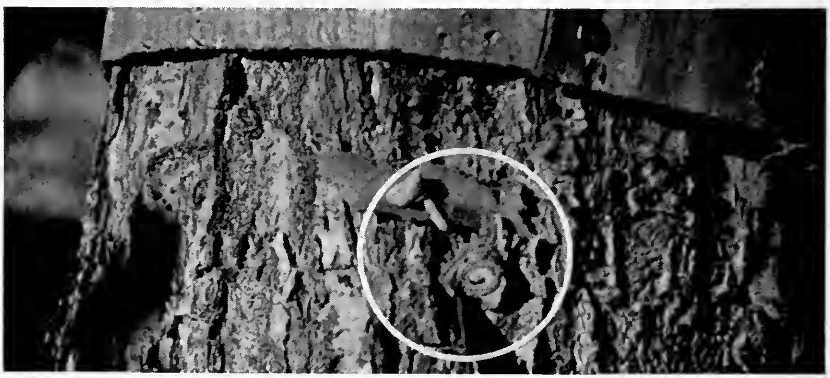
Used baskets harbor codling moth larvae. This basket was one of many stacked in the shed shown above. The empty pupal cases on its rims show where the moths emerged in the spring. Fig. 2

On trees that have been carefully scraped and pruned, chemically treated bands 2 to 4 inches wide are very effective in collecting and killing codling moth larvae. Fig. 3

he got excellent control without screening his shed. Then, too, when fruit is relatively clean, as was his, an open shed becomes less dangerous. Furthermore, screening an open shed is both difficult and expensive.

Table 3. — Relation Between Orchard Sanitation and Codling Moth Control

Orchard	Extent of orchard sanitation			Three-year average infestation	
	1942	1943	1944	Wormy	Stung
				perct.	perct.
1	Very thoro	Very thoro	Very thoro	1.1	8.6
2	Very thoro	Very thoro	Very thoro	2.1	5.6
3	Very thoro	Very thoro	Very thoro	2.7	9.1
4	Very thoro	No banding Orchard kept clear of trash. Packing done away from orchards	No banding Orchard kept clear of trash. Packing done away from orchards	4.1	12.4
5	Good	Trees banded in most of orchard	Trees banded but not scraped	7.9	19.6
6	Good	None except trees well opened	Moderately good	10.3	28.9
7	Trees well scraped but not banded	Little done; no banding	Moderately good	11.1	47.2
8	None	None	None	11.8	43.4
9	None	None	Trees banded, but not scraped. Open shed probably increased infestation	17.5	27.2
10	None	Banded, but trees poorly scraped	Banded, but trees poorly scraped	29.9	14.0
11	None	None	None	31.9	23.5
12	Fair in one orchard, none in other. Shed screened	Little done. Shed screened	Part of orchard banded. Shed screened	52.5	28.8
13	None	None	None	53.3	17.2



This tree was banded but not scraped. The larvae (in circle) were found under the rough bark just below the band. Banding without thoro scraping loses much of its value. Had this tree been scraped, the larvae would have gone under the band.

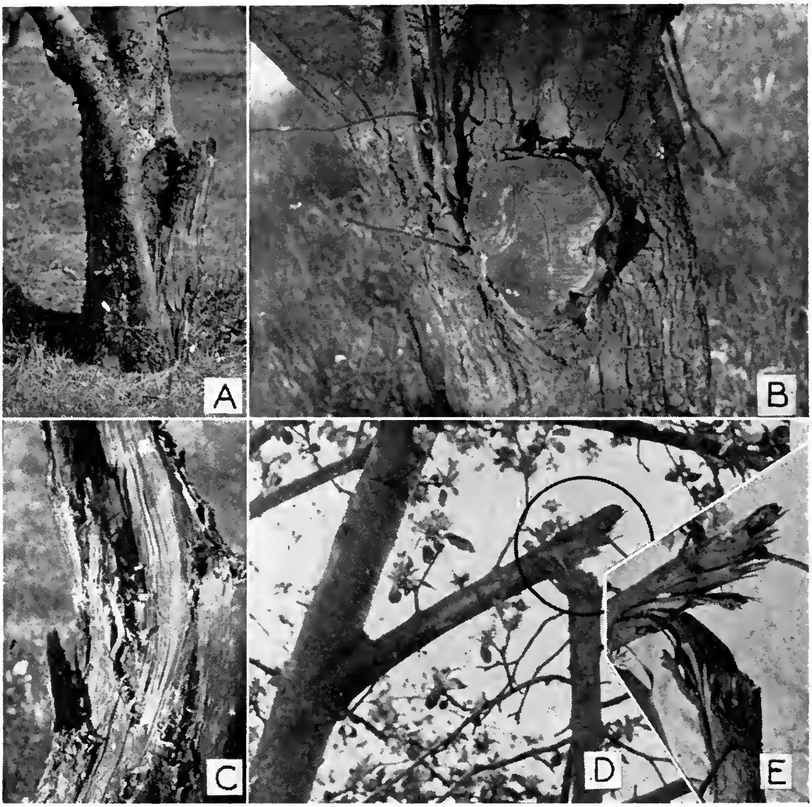
Fig. 4

To scrape these trees, a solid stream of water at 500 pounds pressure was directed at them from a spray gun with a ⅛-inch opening. The water did a good job of removing the bark and cleaning out the holes and crotches, and killed most of the larvae. It takes 3 to 5 minutes and about 25 gallons of water to clean a tree by this method. Fig. 5

Banding, following thoro scraping, is perhaps the most important single item in orchard sanitation. Yet those growers who got the best results from it were the ones who also followed most of the other recommended sanitary practices.

In the past many growers and entomologists have held that the greater the infestation, the greater the need for thoro sanitation; and conversely, the lighter the infestation, the less the need. These studies show, however, that those growers who practiced sanitation most thoroly year after year without regard to infestation consistently produced the cleanest fruit. Moreover, their orchards had the smallest codling moth populations and the lightest carryovers (Table 3).

Sanitation thus appears to be at least as important to control as good spraying and should be a regular orchard practice.



When there are hibernating places like these, control of codling moth by banding is impossible. (A) Decayed trunk; (B) punky wood and rough bark around unhealed pruning stub; (C) splintered crotch; (D) broken limb; (E) break in D enlarged to show hibernating places. Fig. 6

EFFECT OF LABOR SHORTAGE AND SOME PERSONAL FACTORS ON CONTROL

Delayed Spraying and Neglected Sanitation Resulted From Labor Shortage

Owing to wartime conditions, the shortage of labor became of increasing importance as the study progressed. "Spray hands" were scarce and when obtained were not as good as usual. In Orchard 6, for example, some of the spraying had to be done with only one man, who worked in the tower. The customary system uses at least two men, one in the tower and one on the ground or on a low platform. The owners of Orchard 2 reported that they had found it impossible to get good spraymen. The owner of Orchard 8 saved labor by using a speed sprayer.

The labor shortage forced growers to make difficult decisions that often affected codling moth control. For instance, the owners of Orchard 8 secured banding material but were unable to put it on because all the available help was at work on the early apple harvest, which generally coincides with banding time. Certainly failure to band trees affected control of second and third broods.

The labor shortage also sometimes led growers of both late and early apples to neglect spraying during the early apple harvest and during the peach harvest. The delayed spraying meant apples more heavily infested by third-brood larvae. The owners of Orchards 9 and 10 found that the peach harvest interfered with their spray schedule. Other growers at times had the same experience. In such circumstances the grower must decide what is to have priority. His decision, of course, will probably rest on the relative value of the two crops competing for his time and attention, and on his labor supply.

Grower's Attitude Did Not Account for Lack of Control

In general the most successful growers are those who are on the alert for new ideas: they attend fruit growers' meetings; they cooperate with extension and experiment station workers; they seek information from other good growers, and from good books and publications. It is this attitude that is considered here.

The growers in this survey were for the most part the kind of men just described; especially was this true of the owners of Orchards 1, 2, and 3, who obtained good control of the codling moth. But it was also true of the owners of Orchards 5, 6, 9, and 12, especially of 12, tho none of this second group secured satisfactory control.

Examination of Tables 1 and 2 will show that it was not for lack of initiative in learning about better methods that some of these growers failed to get good control, nor did the possession of such initiative assure good control.

Owner's Participation Not Needed for Good Control

Extension men and experiment station workers have often lauded the owner's participation in the spraying of his own fruit. It might be assumed that his sharing of the work and his responsibility as overseer would be of greater importance now when good help is scarce than it was when the study started in 1942.

Study of the orchards in which the owner did help with the spraying, however, does not substantiate the claim that owner spraying necessarily means better results (Table 5). In two of the four cleanest orchards and in two of the four wormiest the owners did the spraying. In Orchards 1 and 3, having somewhat smaller acreages, the owners ascribed their usual success in controlling the insect in part to personal supervision of spraying. In Orchards 2 and 4, having larger acreages, the owners or managers had worked out good systems of spraying and had taught their trusted operators those systems. Afterwards they merely had to check from time to time to see that their instructions were being followed. In the four wormiest orchards, where the owners did help spray, the trouble seemed to be that some were not themselves good spraymen tho their equipment was efficient and that others who were good spraymen had inefficient equipment.

It appears then that while owner spraying is certainly helpful in many cases, it is by no means necessary to success.

EFFECT OF TYPES AND NUMBER OF SPRAY MACHINES AND OF SPRAYING METHODS ON CONTROL

Quality and Quantity of Spray Equipment Are Important

In Orchards 1 to 4 especially, good spray equipment and enough of it contributed materially to the success indicated in Tables 1 and 2. In Orchards 11 and 12 too little equipment was an important cause of poor control.

In some of the orchards one factor offset another. In Orchard 10 the equipment was good and there was enough of it, but inadequate coverage and too little attention to spray schedules resulted in poor control.

Orchard 7 provides the best example of the way factors may counterbalance each other. The equipment was good and was adequate for the acreage. In 1944 in one block only 4.4 percent of the fruit was wormy; yet in another, sprayed by the same men with the same rig, 38.5 percent was wormy (Table 1). The reason for this difference was apparently too little spray in the wormy block (*see pages 321-322*). (The amount of spray to apply will be discussed later.)

A recent development in spraying equipment is the so-called "speed sprayer" shown in Fig. 7. In this machine the spray is pumped out under low pressure thru a large number of jets and blown onto the

This new type of sprayer, called a speed sprayer, is especially adapted to large acreages. It saves more time and labor than the commonly used sprayers and sprays all trees alike. Fig. 7

trees with a continuous blast of air from a propeller similar to that used in airplanes. One of these machines was used in Orchard 8 in 1944, with none too good results, as Tables 1 and 2 show. (For discussion of advantages, *see page 315.*)

The kind and amount of equipment used is closely related to methods of spraying and thoroness.

Thoro Spraying Is Essential

To determine what spraying practices proved effective, spraying methods were closely watched in these orchards thruout the season in each of the three years. It was hoped that at the conclusion of the study Illinois growers could be told both how to spray and how not to spray. Unfortunately the factors involved proved to be so varied and so interrelated that it is not possible to develop a set of simple standardized instructions that will meet all requirements. Certain principles were established, however, and a good many preconceived ideas had to be abandoned.

Tower needed on large trees. All the trees in these orchards were mature, at least 18 feet tall, many taller. Later broods of codling moths can spread to all parts of the tree and of the orchard from apples in the tops that are only lightly covered with spray or missed entirely. Using a tower has been considered a great help in increasing the deposit on apples in the upper parts of these mature trees.

Good coverage

Poor coverage

The tower (left) was used in nonstop spraying in Orchard 5. Being 12 feet from the ground to the platform and 16 feet to the spray nozzles, the outfit allowed the sprayman to cover thoroly the upper parts of any except exceedingly tall trees. The solid stream (right) resulted from poor ground pressure. The use of a spray outfit which did not provide enough ground pressure and which did not have a tower, and failure to open and to reduce the height of trees accounts for much of the heavy infestation in Orchard 11. Fig. 8

Growers' results, however, failed to prove conclusively that the use of a tower did increase the deposit in the tops. The reason is that some of the spray falling from the tops stays in the lower parts of the tree and thus increases the residue on the apples at that level. A tower was used on only one of the four orchards having the lightest infestations (Orchard 2, Table 5), whereas it was used in two of the four most heavily infested (Orchards 12 and 13). Moreover, in Orchard 2, where a tower was used, the deposit in the tops was much lighter than the deposit in the bottoms. It was also lighter than that in the tops in Orchards 1 and 4, where towers were not used.

In Starking Delicious in Orchard 2 (Table 1) control for three years was as good in the tops as in bottoms of trees, perhaps better, a very unusual thing. Such good control was in part achieved by supplementing the regular cover sprays from the tower with occasional top-off sprays. Top-off sprays (sprays of the same formulation applied to the upper one-third of the tree between complete cover sprays) are a regular part of the recommended spray schedule. They are not used as often as they should be.

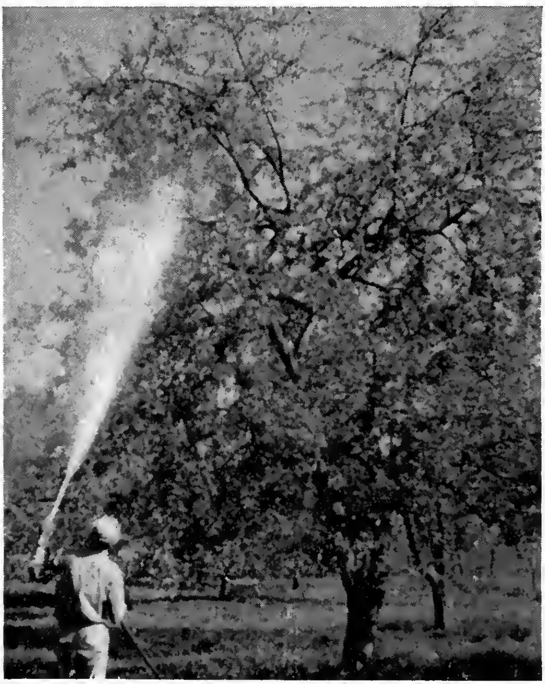
One man who sprayed from the top of the tank with a long-handled broom managed this outfit. It was designed to help meet the labor shortage. The system might have become a good one if enough gallonage had been used and enough applications had been made. Fig. 9

The advantage of a tower is greater in a nonstop than in a stop system. In the time it takes a spray outfit to pass a tree few men have the skill or the time to spray it thoroly from the platform or the ground. Therefore where trees are large, a tower is almost a necessity in a nonstop system.

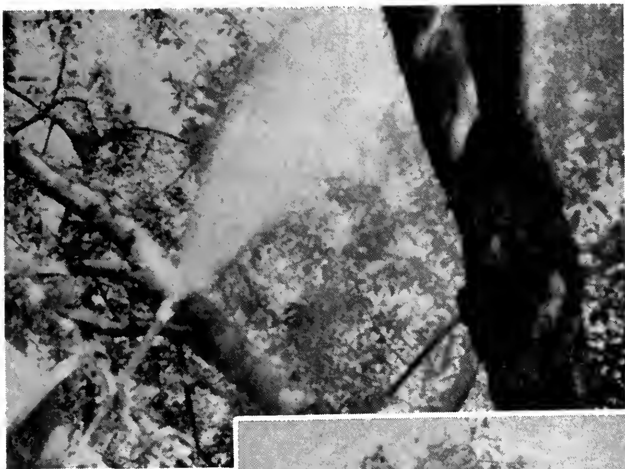
Spraying from tank top gave a uniform deposit. In Orchard 13 (Fig. 9) the owner working alone did all the spraying from the top of the tank. The lead load, tho not heavy enough thruout, was as heavy in the tops as in the bottoms (Table 5); and the infestation was as heavy at one elevation as another (Table 1). The owner of Orchard 12 used the same system with about the same results. If enough spray had been used, the system might have proved good.

Men spraying from the ground got good results. Knowing how some of the men achieved good results without a tower is important (Table 1).

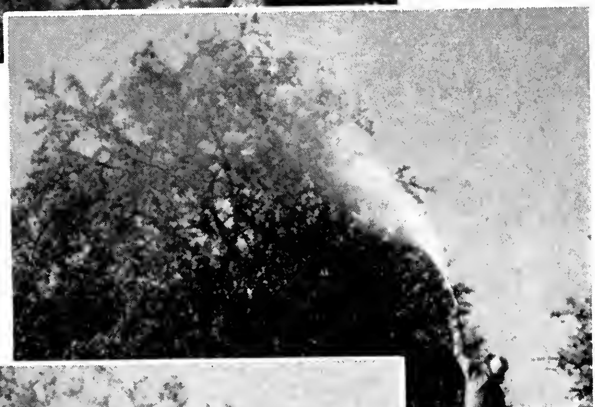
The owner of Orchard 4, a "ground-only" man, used a system consisting of three operations (Fig. 11). First, the sprayman went into the tree and sprayed the inside, up and thru the top of the tree,



The owner of Orchard 1 (left) sprayed entirely from the ground. Good pressure and thoro coverage of well-opened trees were partly responsible for the low infestation in this orchard. Fig. 10



Spraying inside the tree



Spraying all around the tree — top only

Spraying the lower half of the tree

The manager of Orchard 4 used a well-planned system of spraying from the ground. The trees were kept open and the spraying was done by his hired men.

Fig. 11

using good pressure (500 pounds) and wetting everything on the inside. (The trees had been well opened up; that is, pruned for the purpose of spraying from the ground.) Next, he walked around the tree, spraying the upper branches only, trying to "fog it over" the top. And last, he walked back around the tree, spraying the lower branches. When he reached his original position, he was ready to go to the next tree.

In Orchards 1 and 2 the plan was very similar except that if trees were not too large, the inside spraying was omitted (Fig. 10).

Altho no towers were used in these three "best orchards," the owners realize that there are times when they could get better results if they used them (compare worm ratios tops and bottoms, Table 1). A tower does not always seem to them to be essential because they keep the infestation low by other means.

Requirements and Advantages of Nonstop System

For a nonstop system of spraying, a 35-gallon-a-minute pump on a 500-gallon tank powered by a caterpillar tractor is needed. Such a rig can be moved slowly enough to assure a thoro spraying of each tree.

This nonstop spraying outfit was used in Orchard 2. Nonstop spraying is most successful when a tower is used, plenty of pressure and volume maintained, and the trees are well opened up. Fig. 12

One such combination is shown in use in Orchard 2 (Fig. 12). Some growers use guns, some multiple-nozzle brooms on outfits of this type. Both proved effective in these orchards (Table 5). Such equipment saves time, but it should not be used without plenty of pressure and volume.

A power take-off too is often considered an advantage. It may, however, be a disadvantage unless the outfit is drawn by a caterpillar tractor or a tractor specially geared for slow speed. Frequent stopping means shifting gears and a temporary lowering of pressure. It was a disadvantage in Orchard 12, where the owner used a nonstop system even tho his tractor could not travel slowly enough for it. The result was that each tree received only about 6 gallons of spray (Table 5).

Speed Sprayer Saved Time, Labor, and Material

The owner of Orchard 8 used a speed sprayer in 1944 (Fig. 7). A speed sprayer saves time, labor, and material. With it, 500 gallons of spray can be applied in less than half the time required with good conventional equipment. Only two men are needed to operate it; one to drive the tractor and operate the rig, the other to keep the tank supplied. With it all trees are usually sprayed alike regardless of who does the spraying.

The speed sprayer did not, however, prevent an increase in infestation from one year to the next (Tables 1 and 2). Also the percentage of wormy apples was very high in the tops (Table 1).

In Orchard 9 a conveyor was used to fill the spray machine. With it, more spray was laid on per day with less labor. Fig. 13

Summary of Effectiveness of Spraying Equipment and Methods

These studies show the following facts about the way in which different spraying practices built a deposit of material on the fruit and controlled the codling moth:

1. There is no one method that will insure success.

2. Any method is more successful if the trees are opened up properly to let the spray reach the inside of the tree.

3. A nonstop system should be used only when there is plenty of pressure and volume.

4. A nonstop system is of especial advantage when there is a big acreage to cover, as it takes less time than stopping at each tree.

5. A tower is almost a necessity in a nonstop system.

6. A tower is an advantage in any system, but an operator can get good control without it if he makes special effort to reach the tops of the trees from the ground.

7. Topoff sprays are a great help in equalizing the amount of spray in the tops and the lower branches of the tree.

8. The speed sprayer was no more efficient than the usual method except that it saved time, labor, and some material and removed certain variations that usually occur from tree to tree or with different individuals. Trees needed as much topping off with the speed sprayer as when any of the other methods were used.

EFFECT OF VARIOUS SPRAY SCHEDULES AND OF SPACING ON CONTROL

Common Spray Schedules Gave Good Control

Growers used two insecticides — lead arsenate and nicotine. Most of them applied lead arsenate early and nicotine late in the season (Table 4). A few growers used lead arsenate chiefly, bolstered by nicotine sulfate. Others used lead arsenate only as the calyx and the first or the first and second cover and thereafter used nicotine alone. Typical examples of these three most commonly used spray schedules are shown on the next page.

Some growers used "fixed" nicotine, that is, nicotine combined with some form of bentonite to produce a stomach poison. Others used a combination of lead arsenate and nicotine, sometimes following the

	Calyx spray and first-brood sprays, dates					
Lead arsenate early, nicotine late						
Lead arsenate	4/28	5/10	5/17	5/22	6/1	6/9
Nicotine						
Lead arsenate only	4/24	5/4	5/25	6/1		
Nicotine only, after 1st or 2d cover						
Lead arsenate	4/27	5/10	5/17			
Nicotine				5/27	6/23	
	Second- and third-brood sprays, dates					
Lead arsenate early, nicotine late						
Lead arsenate						
Nicotine	7/11	7/20	7/30	8/4		
Lead arsenate only	7/3	7/11	7/21			
Nicotine only, after 1st or 2d cover						
Lead arsenate						
Nicotine	7/9	7/16	7/25	8/5	8/23	9/1

"split" schedule[1] in which lead arsenate and nicotine are combined, applied twice, and followed during rest of season by nicotine alone.

The schedules varied somewhat from year to year and in some orchards from block to block. The schedule used in a given orchard may be determined by consulting Table 4, the result of its use by referring to Tables 1 and 2. The spray schedules used by the thirteen orchards in 1944 are given on pages 329 and 330.

Among the orchards that received only lead arsenate, two (Orchards 1 and 2) had uniformly good control and two (Orchards 11 and 13) had uniformly poor control in each year of the study. The few orchards receiving only nicotine were for the most part but lightly infested. The group that received lead arsenate early and nicotine late in the season included some orchards with good and some with poor control.

Owing to hot, dry weather, lead arsenate was less effective in 1944 than nicotine; yet Orchards 1 and 2, sprayed with lead arsenate that season as in the two previous years, still had the lowest infestations. These orchards are further examples of the way an unfavorable factor such as weather may be counterbalanced by a favorable factor, in this case good orchard sanitation.

Good results can apparently be secured from any one of the commonly used spray schedules.

Timing of sprays. Most of the growers in the survey made some effort to time their sprays by following spray-service announcements, applying their sprays at critical times. Where these critical times are

[1] For directions for using the "split" schedule, see Circular 568, "Pest Control in Commercial Fruit Plantings," page 15.

Table 4. — Insecticides Used Chiefly or Entirely in Thirteen Orchards,[a] 1942, 1943, and 1944

	Orchards where *lead arsenate* was used thruout the season	Orchards where *nicotine* was used thruout the season	Orchards where *lead arsenate* was used early, *nicotine* late
1942, Orchards.	1, 2, 4[b], 6, 7, 8, 11, 13	4[b]	3, 5, 9, 10, 12
1943, Orchards.	1, 2, 7, 8, 11, 13	3, 4	5, 6, 9, 10, 12
1944, Orchards.	1, 2, 8, 11, 13	3, 4, 7	5, 6, 9, 10, 12

[a] Numbers apply to same orchards as in Tables 1 and 2.
[b] In 1942, Orchard 4 included both lead and nicotine blocks.

covered by a comprehensive spray schedule — that is by spaced sprays — exact timing is, however, less important than otherwise.

The growers who paid no attention to the timing of sprays — as, for instance, the owner of Orchard 13 — got poor results. The owners of Orchards 1 and 2 achieved excellent results by delaying their first spraying until the first eggs were ready to hatch. They recorded the dates on which the moths appeared in emergence cages, calculated the dates when the eggs in the orchards should hatch, and timed their spraying to coincide with the appearance of the first larvae.

Under certain conditions, timing toward the end of a season may be highly important. Such conditions existed in 1943 and 1944, when hatching continued later than usual. Growers included in this survey heeded and profited by the general spray warnings. The owner of Orchard 4 maintained bait traps to determine proper timing, including sprays for the late brood.

If, however, orchards are especially free from infestation, as were Orchards 1 and 2, timing late in the season may not be important. Most blocks in those orchards received no sprays after the first week in July, some none after the last of June. For those growers the battle was over by the time the attack of the second brood was getting under way. Their low carryover, excellent orchard sanitation, and thoro destruction of the first brood had so reduced their insect population that they could safely disregard the proper timing of late-season spraying.

Closely Spaced Sprays Gave Best Results

In orchards having a heavy carryover, or in orchards in the three-brooded area that are subjected to moderate to severe infestation, it is advisable to apply sprays frequently enough to insure protection of the fruit all the time. In these studies frequent spraying proved especially desirable where nicotine (which does not retain its residual toxicity as well as lead arsenate) was used. In Orchards 3 thru 8 the spray was ordinarily applied frequently enough, but there were some instances in which the time between sprays was too long; namely, in Orchards 5, 6, 7 in 1942, in Orchards 6, 8 in 1943, and in Orchards 7 and 8 in 1944.[1]

Orchards 1 and 2 seemed the exception to the rule. Both received practically all their sprays during the first-brood period; in some cases they had one spray in the second-brood period. By keeping the infestation low, the growers were able to crowd most of their spraying into the first-brood period, making it easier to meet the lead tolerance at harvest.

FACTORS CAUSING GOOD POISON DEPOSIT

A good deposit of poison on the fruit is important, as this study demonstrates. Unless enough poison is deposited on the apples, control is likely to be poor in spite of everything else the grower does or does not do. Conversely, a good deposit of poison on the fruit thruout the period when the insect is attacking often results in good control even tho some of the growers' methods may be poor.

Because a good deposit is extremely important, it seems necessary to discuss in some detail those factors relating to it.

High Concentration Was Superior to Low

Under the conditions of the study it was impossible to consider concentration apart from the influence of other factors. It is generally conceded that high concentrations give heavier deposit and better control than low. These high concentrations appear to have been responsible for better control in the following instances:

In Orchard 1, 4 pounds of lead arsenate and 3 quarts of summer oil in 100 gallons of spray, rather than the usual amounts — 3 pounds of lead and 2 quarts of oil.

In Orchard 7, in 1943, the same high concentration appeared to be

[1] The following spray intervals were too long:

Orchard 5, 1942: June 9 to July 8; July 21 to August 12. Orchard 6, 1942: June 2 to July 3. Orchard 7, 1942: June 11 to July 3; July 16 to August 21.

Orchard 6, 1943: July 28 to August 27. Orchard 8, 1943: June 7 to July 6.

Orchard 7, 1944: July 19 to August 11. Orchard 8, 1944: July 26 to August 17.

partly responsible for the low percentage of wormy apples shown in Tables 1 and 2.

In Orchard 11 the reduction in percent of wormy Delicious apples in 1943 over 1942 (Table 1) was without doubt due partly to the high concentrations of lead arsenate and oil used in a greater number of applications.

In Orchard 9 the use in all three seasons of only 1 quart of summer oil in 100 gallons of spray (to avoid injury to foliage) is partly responsible for the mediocre control shown in Tables 1 and 2. Also, the poor control in Orchard 12 in 1943 and 1944 resulted in part from using lead arsenate and nicotine in concentrations too low to offset the effects of the heavy carryover.

Large Number of Applications Proved Unnecessary

Presumably two sprays at half strength might leave the same deposit as one spray at full strength. Fruit growers have often been told that the greater the number of applications the better the control, an idea that would seem logical, at least in orchards having a heavy infestation.

Comparison of these thirteen representative orchards does not, however, appear to show that those having the most applications did

Table 5. — Three-Year Spray Record of Thirteen Illinois Orchards, 1942, 1943, 1944

Orchard[a]	Average poison sprays	Gallons per tree	Owner sprayed	Tower used	Spray system	Lead residue, grains per pound of fruit[b]		
						Top	Bottom	Ratio, top to bottom
1	5	12	Yes	No	Stop	.053	.073	1 to 1.3
2	9	12	No	Yes	Nonstop	.022	.042	1 to 1.9
3	11	9	Yes	No	Stop	.047	.123	1 to 2.6
4	12	22	No	No	Stop	.176	.213	1 to 1.2
5	10	12	Yes	Yes	Nonstop (mostly)	.030	.052	1 to 1.7
6	9	18	No	Yes	Stop	.089	.144	1 to 1.6
7	9	8	No	No	Stop	.076	.100	1 to 1.3
8	11	16	No	Yes	Stop[c]	.123	.241	1 to 1.9
9	10	16	Yes	Yes	Stop	.026	.164	1 to 1.6
10	9	6	No	No	Stop	.008	.021	1 to 2.5
11	8	7	Yes	No	Stop	.039	.103	1 to 2.6
12	7	6	No	Yes	Nonstop	.069	.090	1 to 1.3
13	2	8	Yes	Yes	Stop	.026	.022	1 to .8

[a] Numbers apply to same orchards as in previous tables.

[b] Three-year average in Orchards 1, 2, 5, 6, and 8 to 13. Two-year average in Orchard 7. One-year record for Orchards 3 and 4.

[c] Nonstop system used with speed sprayer in 1944 in Orchard 8.

have the best control. Disregarding the unusual and very much neglected Orchard 13, and comparing Orchards 1, 2, and 3 with Orchards 10, 11, and 12 (Table 5), we find the average number of poison applications (eight) to be practically the same in both the three lightly and the three heavily infested orchards. The average percent of wormy and stung fruit for both groups is shown in Table 2. More sprays would probably have helped Orchards 10 to 13, but it is doubtful whether they would have done anything for Orchards 1 to 4.

The remarkable thing is that (with the exception of the neglected Orchard 13) the cleanest orchard in the survey, Orchard 1, received the fewest sprays. Here again we have compensating factors, some of which have already been mentioned, that allowed the owners of Orchard 1 to get along with fewer sprays.

Thoroness of Application

It did not take these studies to establish the fact that thoroness of spraying affects the amount of deposit and the control of the insect, but the study does emphasize that fact. The best jobs of spraying were probably done in Orchards 1, 2, and 4, and the least thoro in Orchards 11 and 12 (Tables 1, 2, and 5).

Enough Spray

Obviously, if there is not too much runoff, the greater the amount of spray applied to a tree, the greater will be the amount deposited on the fruit and consequently the better the control of the insect. Many experiment-station workers have urged heavy applications, recommending ¾ to 1 gallon of spray for each year of tree age. By this standard, trees twenty years old or older, such as those in this study, should receive from 15 to 20 gallons each. Trees in only four of the thirteen orchards, however, received such large amounts. Those in the most successful orchards received only moderate amounts of spray.

Very low gallonage, however, certainly makes for poor codling moth control. For instance, the four most heavily infested orchards, 10 to 13, received an average of only 6.75 gallons of spray per tree, whereas the four most lightly infested orchards, 1 to 4, received an average of 13.75 gallons (Table 5).

That the amount of spray is important was shown most clearly in Orchard 7 (page 308). The tremendous difference in infestation between the two blocks in this orchard in 1944 (Table 1) resulted from scrimping the spray on one block. One of the spray operators, having a financial interest in the crop from Block 2 and having to pay for the spray, tried to save money by reducing the gallonage.

The amount of deposit at harvest would be expected to be related to number of sprays applied and the gallonage applied. It was not possible to find what the relation was, however, because of the time which elapsed between the last spraying and the time when samples for analysis were taken and also because of weathering and variations in concentration. There should also be some relation between lead analysis, number of sprays, gallonage, and control; but this relation would be still more difficult to ascertain since nicotine was sometimes used as well as lead, whereas only the lead was analyzed.

The lead analyses in Table 5 do not include full three-year records for Orchards 3, 4, and 7 because in these orchards only two or three of the sprays included lead arsenate and the rest were nicotine. All the records are valuable, however, as a means of comparing the residue in the tops and bottoms of trees and will be considered later.

One of the important facts this study brings out is that heavy residues at harvest do not always mean good control. In Orchard 8, receiving 11 lead arsenate sprays and having a heavy residue, the control was poorer than in Orchards 1, 2, and 3, which had much lower lead deposits. In Orchard 2, the second cleanest, the harvest residue was very light, largely owing to the fact that the 9 sprays were all applied early in the season and without the summer oil, which makes the poison stick to the fruit.

Proper Pruning

Pruning is thought of mainly as a way to shape and invigorate a tree. Properly done, however, it will also help materially to control codling moth. Growers will get the best results from pruning as a means of controlling codling moth if they will be careful to do these things:

1. Clear out all dead and broken branches, especially if they contain punky wood.
2. Remove split branches, whether the branches are large or whether they have small cuts at the ends.
3. Make cuts close, so as not to leave stubs.
4. Remove any stubs left from former prunings.
5. Lower the tops of trees that have grown so tall as to make it hard to get enough spray to the upper part of the tree with the equipment at hand.
6. Open up trees enough to let spray reach and properly cover the apples in all parts of the trees.

This tree was so thick the spray could not penetrate it. The apples on the inside were not well covered. Fig. 14

This tree is so well opened up that spray can reach apples in all parts of it. The trees in the most lightly infested orchards in the survey were kept open to a similar extent. Fig. 15

The first four practices — removing dead and broken branches, split branches, stubs, and making cuts close — gets rid of many of the hiding places of cocoons and thus makes the bands more effective.

The last two practices — lowering the tops of trees and opening the trees — make it easier to lay a good deposit of poison on the fruit in all parts of the tree and do it with somewhat fewer gallons per tree. Opening up the tree is especially important in a nonstop system, for in that

These apples were on a thick tree such as that shown in Fig. 14. Compare the spray deposit on the fruit (left) with that on the reverse sides of the apples (right). The tree was so dense that the spray, applied from the side of the tree opposite the apples, could not reach them. Fig. 16

system there is no way for an operator to take advantage of openings in a tree that in general is too thick.

The owners of Orchards 1 to 4 followed these pruning practices. The owners of Orchards 10 to 13 either neglected them, followed only part of them, or did not apply them thruout the orchard.

Tho topping of trees does result in better control in the upper parts of the tree, it is sometimes a questionable practice, for the topped area may sun-scald. The owner of Orchard 6 topped his trees and thereafter was better able to reach the upper parts of them.

Reducing the height of trees by removing the highest branches makes it easier to control codling moth in the tops. Fig. 17

Use of Summer Oils and Stickers

That a deposit of spray can be built up with summer oils and stickers is hard to prove except in carefully replicated experiments. There were several instances in this survey, however, in which better control seemed to come from heavy dosages of summer oils. Those oils kill insect eggs and also make lead arsenate stick. Evidence of the effect of summer oils on control was discussed under *High Concentration Was Superior to Low,* pages 319-320.

The owner of Orchard 2 achieved good control in the three-brooded area in a unique way. For three years he used soybean flour as a spreader and sticker with lead arsenate instead of summer oil. Eight or nine such lead arsenate sprays were crowded into May and June, no sprays being applied after that time. The lead tolerance was met (Table 5) and control was excellent. It is probable, however, that this plan would not have been successful had not the carryover been reduced by careful and thoro spraying, orchard sanitation, and proper pruning. The owner of Orchard 9 tried to follow this procedure, but he used too few first-brood applications. He failed to get good control even tho he used several second-brood nicotine sprays.

Resistant Strain May Explain Some Failures Despite Good Deposit

It has been cited as a rule that if enough spray is kept on the fruit, control of codling moth can be achieved even when some of the methods used by an orchardist are poor. There seems to be one circumstance that creates an exception to this rule—that is the development of a strain of codling moth that is somewhat resistant to lead arsenate, for it has been established that such a strain may develop under some circumstances.

Such a strain may have been present in Orchard 8 in 1944, for this was a season when lead arsenate was not as effective as nicotine. In this orchard the grower had used a heavy lead arsenate program for years. Ten to 12 sprays containing 4 pounds of lead arsenate per 100 gallons of spray had been applied, many of them containing summer oil. Since the deposit on the fruit was high in 1944 (Table 5), the poor results may have been due in part to the insects' having developed resistance to this material. It is impossible, however, to be certain that this was the cause.

It is quite likely that the building up of resistance to lead arsenate has been prevented in some of the other orchards by the use of less lead arsenate. When, thru sanitary and other measures, a grower has been able to reduce the number of lead arsenate applications or to crowd them into the period when only one of the three broods of the season is working, the likelihood of building up a resistant strain of codling moth is remote.

SUMMARY AND CONCLUSIONS

What are the lessons to be gained from this three-year study of thirteen southern Illinois orchards, and what are their practical value?

Perhaps the first answer is that every grower who tries to control codling moth will find certain conditions or practices offsetting other conditions or practices in whole or in part. This means that a grower who follows certain good practices may safely give less attention to others and thereby save time, money, or labor, or accomplish other desired purposes. But the reverse is also true: a grower who neglects some practice may get poor control despite his careful adherence to other good and well-established practices.

The relative importance of some of these compensating factors will be seen more clearly by a study of Table 6. From this table we may conclude that for the successful control of codling moth the most important practices are not a certain method of spraying, or the use of a certain insecticide, or the length of the spray schedule, or the participation of the owner in the actual spraying operations. The really essential factors appear to be these:

1. Reduction of insect numbers to a low level by the use of thoro sanitary measures.

2. Thoro spraying of trees that have been well opened up to let the spray material penetrate into the interior.

3. Use of enough spray material per tree to insure coverage, but avoiding putting on so much that fruit will not meet the tolerance test.

4. The efficient use of the spray material.

The ideal way to get good control of this destructive pest is to so cut down the first-brood numbers that little spraying will be needed for the second and third broods. This was done in Orchards 1 and 2. These growers did not, however, reach their goals in a single season; it took them several seasons to do it. Other careful growers who will follow the four practices listed above can reach such a goal in a few years.

(See Table 6 on next page)

Table 6. — Some Significant Facts About Control Methods Used in Two Groups of Orchards: 1942, 1943, and 1944

Factor	Four **LEAST INFESTED** orchards (carryover low in all)	Four **MOST HEAVILY** infested orchards (carryover high in all)
1. **Spray material**	Lead in 2 orchards, nicotine in 2	Lead in 2 orchards, combination in 2
2. **Second-brood spray schedule**	Short in 2 orchards, long in 2	Short in 2 orchards, long in 2
3. **Number of applications**	5, 9, 11, 12 (3-year averages for Orchards 1 to 4)	9, 8, 7, 2 (3-year averages for Orchards 10 to 13)
4. **Gallons per tree**	12, 12, 9, 22 (3-year averages for Orchards 1 to 4)	6, 7, 6, 8 (3-year averages for Orchards 10 to 13)
5. **Spray methods**	Very thoro in all	Not so thoro
	Nonstop in 1 orchard, stop at tree in 3 orchards	Nonstop in 1 orchard, stop at tree in 3 orchards
	Power take-off in 1 orchard, horsedrawn in 3 orchards	Power take-off in 2 orchards, horsedrawn in 2 orchards
	Owner-sprayed in 2 orchards, 2 not owner-sprayed	Owner-sprayed in 2 orchards, 2 not owner-sprayed
	Tower used in 1 orchard, not used in 3 orchards	Tower used in 2 orchards, not used in 2 orchards
6. **Pruning**	Trees pruned and opened up in all orchards	Trees not pruned enough nor opened up enough
7. **Equipment**	Good, and enough for acreage	Not enough, and quality too low except in 1 orchard
8. **Sanitation**	Good in all 4 orchards	Omitted entirely in 2 orchards, poorly done in 2 orchards

Appendix

SPRAY SCHEDULES USED BY THIRTEEN ORCHARDISTS IN 1944

Orchard	Applications and dates[a]	Materials and amounts per 100 gallons
1	Calyx (4-26)	LA 3 lb., lime 3 lb., WS 6 lb.
	1 (5-3)	Sulfur dust
	2 (5-3)	LA 4 lb., lime 2 lb., DLS 8 lb.
	3, 4, 5 (5-23, 6-1, 30)	LA 4 lb., Bdx ½-1, SO ⅔ gal.
2	Calyx (1-5, 5-5)	Oil dust
	2, 3 (5-11, 18)	LA 4 lb., lime 5 lb., SF ¼ lb., WS 4 lb.
	4, 5 (5-25, 31)	LA 4 lb., lime 5 lb., SF ¼ lb., WS 4 lb., BL-40 1 pt.
	6, 7, 8 (6-5, 13, 18)	LA 4 lb., lime 5 lb., SF ¼ lb.
3	Calyx (4-25)	LA 3.2 lb., lime 3.2 lb., LLS 1 gal., WS 5 lb.
	1, 2 (5-3, 8)	LA 3.2 lb., lime 6.4 lb., WS 8 lb.
	3 (5-17)	SBO 1½ pt., WB 5 lb., BL-40 1 pt.
	4, 5, 6 (4-24, 6-1, 24)	SO 2 qt., WB 5 lb., BL-40 1 pt.
	7, 8, 9 (7-5, 13, 24)	SO 3 qt., BL-155 3 lb.
	10, 11, 12 (8-4, 11, 22)	SO 2 qt., BL-155 3 lb.
4	Calyx (4-24)	LA 3 lb., lime 3 lb., WS 4 lb.
	1 (5-1)	LA 4 lb., WS 4 lb.
	2 (5-10)	WB 1 lb., BL-40 1 pt., WS 4 lb.
	3, 4, 5 (5-15, 23, 30)	SBO 1 qt., WB 5 lb., BL-40 1 pt.
	6 (6-13)	SO 2 qt., BL-155 2 lb., BL-40 ½ pt.
	7, 8, 9, 10 (6-22, 7-3, 10 20)	SO 2 qt., BL-155 2 lb.
	11 (8-1)	WB 1 lb., Nicosol 2 qt.
	12, 13 (8-16, 9-5)	SO 2 qt., BL-40 1 pt.
5	Calyx and calyx top-off (4-29, 5-3)	LA 3 lb., lime 3 lb., WS 6 lb.
	1 (5-11)	LA 4 lb., lime 2 lb., WS 6 lb.
	2 (5-19)	LA 4 lb., lime 4 lb., SF ¼ lb., BL-40 1 pt.
	3 (5-25)	LA 3 lb., SO 2 qt., BL-155 1½ lb., BL-40 ⅔ pt.
	4 (6-6)	LA 3 lb., SO 2 qt., BL-155 1½ lb.
	5 (6-13)	SO 2 qt., BL-155 3 lb.
	6, 7, 8, 9, 10 (6-28, 7-13, 27, 8-8, 18)	SO 2 qt., BL-155 2½ lb.
6	Calyx (4-27)	LA 2 lb., lime 2 lb., LLS 1 gal., WS 2½ lb.
	1 (5-2)	LA 3 lb., lime 3 lb., LLS 1 gal., WS 5 lb.
	2 (5-8)	LA 4 lb., lime 4 lb., LLS 1 gal., WS 5 lb.
	3 (5-18)	LA 4 lb., lime 4 lb., SF ¼ lb.
	4 (5-29)	LA 3 lb., Bdx ¾-2, SO 2 qt.
	5, 6 (6-9, 7-1)	LA 3 lb., SO 2 qt., SF ¼ lb., BL-155 1½ lb.
	7 (7-14)	LA 2 lb., SO 2 qt., BL-155 1½ lb.
	8, 9, 10 (7-26, 8-8, 21)	SO 2 qt., BL-155 3 lb.
7	Calyx (4-26)	LA 3 lb., lime 6 lb., WS 6 lb.
	1 (5-5)	LA 4 lb., lime 4 lb., WS 6 lb.
	2 (5-12)	LA 4 lb., Bdx ½-1
	3 (5-19)	LA 4 lb., BL-155 1½ lb.
	4, 5, 6, 7, 8 (5-26, 6-2, 9, 7-1, 19)	SO 2 qt., BL-155 2 lb.
	9, 10, 11 (8-11, 24, 9-6)	SO 2 qt., BL-155 1 lb., BL-40 1 pt.

[a] Dates (given in parentheses) are those on which sprays were started. Sometimes spraying was done from two sides, the second side being sprayed a few days after the first.

SPRAY SCHEDULES — Concluded

Orchard	Applications and dates[a]	Materials and amounts per 100 gallons
8	Calyx 1, 2 (4-24, 5-5, 11)	LA 4 lb., SNL 1 lb., DLS 4 lb., WS 4 lb.
	3 (5-17)	LA 4 lb., SO 1 qt., SNL 1 lb., SL ¼ lb.
	4 (5-23)	LA 4 lb., SO 3 qt., SNL 1 lb., SL ¼ lb.
	5, 6 (5-31, 7-1)	LA 4 lb., SO 3 qt., SNL 1 lb., SL ¼ lb., BL-40 ¾ pt.
	7 (6-13)	LA 4 lb., SO 3 qt., SNL 1 lb., SL ¼ lb.
	8 (7-7)	LA 4 lb., SO 3 qt., SNL 1 lb., SL ¼ lb., BL-40 ¾ pt.
	9, 10 (7-14, 26)	LA 4 lb., SO 3 qt., SNL 1 lb., SL ¼ lb.
	11 (8-17)	LA 4 lb., SO 3 qt., SNL 1 lb., SL ¼ lb., BL-40 ¾ pt.
9	Calyx (4-24)	LA 3 lb., lime 2½ lb., WS 6 lb.
	1, 2 (5-8, 12)	LA 4 lb., lime 3 lb., WS 5 lb.
	3, 4, 5 (5-20, 29, 6-13)	LA 4 lb., lime 2 lb., SF ¼ lb.
	6, 7 (7-10, 21)	BL-155 3 lb., SO 2 qt.
	8 (8-5)	BL-40 1 pt., MB 1 lb., SO 1 qt.
	9 (8-23)	BL-155 3 lb., SO 1 qt.
10	Calyx and calyx top-off (4-26, 28)	LA 3 lb., lime 3 lb., WS 1 lb.
	1 (5-8)	WS 6 lb.
	2 (5-11)	LA 4 lb., lime 4 lb., WS 8 lb.
	3, 4 (5-23, 29)	LA 3 lb., SO 2 qt., BL-155 3 lb.
	5 thru 10 (6-6, 26, 7-10, 20, 8-10, 21)	BL-155 3 lb., SO 3 qt.
11	Calyx (4-25)	Oil dust
	1 (5-5)	LA 4 lb., lime 4 lb., DLS 4 lb., WS 6 lb
	2 (5-11)	LA 4 lb., lime 4 lb., WS 1 lb.
	3 thru 6 (5-23, 6-6, 7-31, 8-28)	LA 4 lb., Bdx 1-2, SO 3 qt.
12	Calyx (4-25)	LA 3 lb., lime 3 lb., LLS 3 qt., WS 4 lb.
	1 (5-8)	LA 4 lb., lime 3 lb., LLS 3 qt., WS 4 lb.
	2 (5-16)	LA 4 lb., lime 3 lb.
	3 (5-25)	LA 4 lb., Bdx ½-1
	4 (5-29)	LA 4 lb., Bdx ½-1, SO 2 qt.
	5 (6-13)	LA 4 lb., BL-155 1½ lb., SO 2 qt.
	6 (7-3)	LA 3 lb., BL-155 1½ lb., SO 2 qt.
	7 (7-12)	LA 2 lb., BL-155 1½ lb., SO 2 qt.
	8 (8-1)	Nicosol 2 qt.
	9 (8-21)	BL-155 2½ lb., SO 2 qt.
13	Calyx (4-24)	LA 3 lb., lime 3 lb., LLS 1 gal., WS 3 lb.
	1 (5-15)	LA 3 lb., lime 3 lb., LLS 1 gal., WS 3 lb.

Key to Abbreviations

LA — lead arsenate
WS — wettable sulfur
LLS — liquid lime sulfur
DLS — dry lime sulfur
Bdx — bordeaux mixture (copper sulfate — lime)
SF — soy flour
SBO — soybean oil
SO — summer oil
BL-40 — Black Leaf 40 (40% nicotine sulfate), Tobacco By-Products Co.
BL-155 — Black Leaf 155 (fixed nicotine), Tobacco By-Products Co.
WB — Wyoming Bentonite
MB — Mississippi Bentonite
SNL — Safe-N-Lead, Sherwin Williams Co. safener
SL — Spray-lastic, Sherwin Williams Co. sticker

[a] Dates (given in parentheses) are those on which sprays were started. Sometimes spraying was done from two sides, the second side being sprayed a few days after the first.

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NOTE ON 1945 AND 1946 TESTS WITH DDT

Effects on control. In 1945, the year following completion of this study, DDT was used experimentally in some orchards included in the study. In 1946 it was very generally used in orchards all over the state.

The results showed that the superiority of DDT as an insecticide did not make up for poor spraying and other poor practices, nor offset lack of sanitation.

In one DDT block, for instance, in which the tops were not getting enough spray, infestation in the tops reached 14.3 percent, while only .3 percent of the apples in the bottoms were wormy. In another instance, a grower who had a light crop used 10 applications of DDT and yet got only fair control. Two things seem to have prevented him from securing good control: first, he had trouble getting his spraymen to do a thoro job on a light crop; second, the proportion of codling moth larvae to apples was so high as to make control especially difficult.

Possible dangers. The 1945 tests showed that the use of DDT in orchards has several drawbacks. When combined with oil, DDT caused injury. In some DDT blocks the fruit was greener and more russeted than in other blocks.

Moreover, DDT kills the parasites and predators which destroy mites, red spiders, and other potential pests. Thus DDT gives these pests a chance to increase.

In 1946 the red-banded leaf roller, an insect which had never been a serious pest in Illinois orchards, appeared in many orchards sprayed with DDT. In some of those orchards it injured as much as 20 percent of the fruit and became a more serious problem than that of the codling moth. Present information seems to indicate that the heavier the application of DDT, the greater the infestation with red-banded leaf roller. Apparently the increase occurred because DDT kills the insect's natural enemies and because DDT is not as effective as lead arsenate in controlling the insect.

To keep these various pests in check, it will be necessary to use as little DDT as possible to control codling moth. Those growers who use it will therefore need to be extremely careful in all their work and will perhaps have to give special attention to sanitation.

Residue problem. The use of DDT as a spray creates a residue problem similar to that created by the use of lead arsenate. DDT is hard to wash off the harvested fruit, and few growers are equipped to wash fruit anyway. Since the tolerance test has to be met, all good practices that will reduce the number of sprays required for control will help to solve the problem of residue.

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