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The Codling Moth Problem in Missouri

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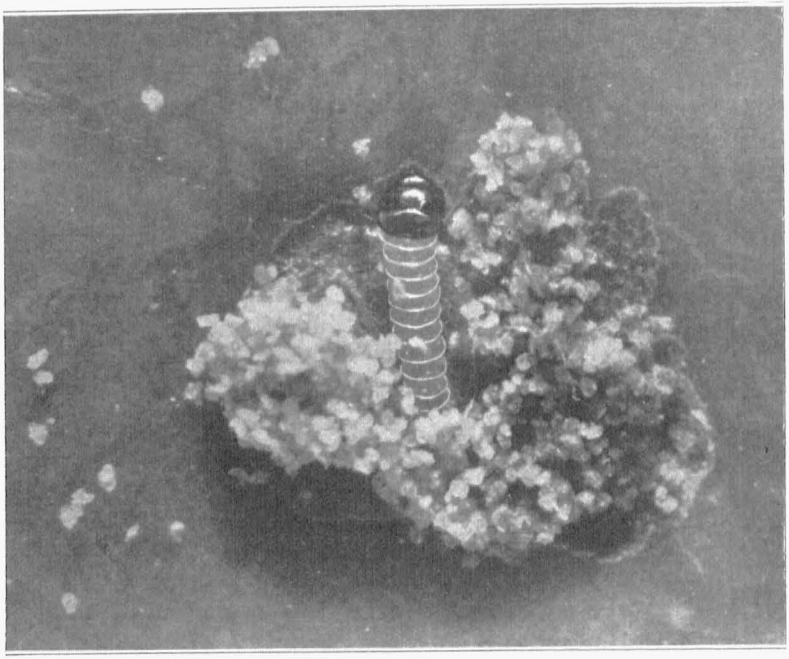

Young larva surrounded by discarded cutting of fruit peel and pulp at entrance puncture which it had already completed. Much enlarged.

COLUMBIA, MISSOURI
APRIL, 1934

SUMMARY AND RECOMMENDATIONS

1. The codling moth has been increasing in Missouri for several years, due to climatic conditions, to the residue controversy, to the necessity of cutting costs, and to other factors.

2. In many of the older, well managed orchards and in most of those just coming into bearing worm populations are still small, so that a moderately heavy spray schedule, combined with continued careful sanitation, will give control. Such a spray schedule should include 2 to 3 pounds of arsenate of lead to 100 gallons with the usual fungicide in the calyx and two or possibly three first brood cover sprays, and 2 pounds of arsenate of lead to 100 gallons in two or possibly three cover sprays properly timed for second and third brood worms.

3. Where worm populations are large and where spray control has not been satisfactory a heavier spray schedule must be combined with supplementary controls, including scraping and banding, moth-proofing the packing house, disposing of hibernating worms in used equipment, picking wormy fruits, and the disposal of wormy drops and culls.

4. Under such conditions special effort should be made to thoroughly control the first brood worms and the spray schedule should include: 2 to 3 pounds of arsenate of lead to 100 gallons with the usual fungicide in the calyx spray; 3 to 4 pounds in the first cover; either 4 pounds, or 3 pounds plus 1 gallon of summer oil emulsion to 100 gallons, in the second and third cover sprays; 3 pounds in the fourth and fifth or July sprays; 2 or 3 pounds in the sixth or early August spray; and 2 pounds in the seventh or late August spray. With heavy doses of arsenate of lead, when no fungicide is used, lime should be used in at least equal parts to prevent spray burn.

5. In timing the sprays each orchard is an individual problem, but the activity of the moths and worms should be used as a guide.

6. By moth-proofing the packing shed or by moving it from the orchard and by treating or storing the infested containers, thousands of moths should be prevented from escaping to the orchard.

7. Trees with scaly bark should be scraped and all scrapings destroyed, preparatory to the use of bands.

8. Tree bands should be used in all heavily infested orchards, preferably the chemically treated corrugated paper bands. Do not use chemically-treated bands on young, smooth-barked trees, as they are apt to injure the trees.

9. Where infestation is serious, the picking of wormy fruits, as in thinning, and the frequent gathering and destroying of wormy drops and culls will destroy many worms and help to make control possible.

10. While it is of prime importance that the grower shall control the codling moth first of all, he must not lose sight of the fact that increased dosages and increased number of sprays will not only pile up excess residue but also add to cost and the danger of spray burn.

The Codling Moth Problem in Missouri

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All attempts to control the codling moth in Missouri, as well as in other important apple growing regions, in recent years have been attended by steadily increasing difficulty. The factors chiefly responsible for this situation have been weather conditions favorable to the moth, abundance of food, reduction of natural checks, and the attempts of orchardists to meet spray residue requirements.

During the last four years, in particular, relatively mild winters and warm, dry summers have been exceptionally favorable to moth increase. Conditions favoring high winter survival and rapid summer multiplication, with three full broods, are bound to increase the problem of control. Partial to full crops of apples for several years have provided abundant food for rapid increase of the pest over most of the State. Moreover, there has been no corresponding increase in natural checks or competitors for the same food supply. On the contrary, there has been a tendency toward decrease of beneficial birds in most orchard regions.

The residue problem has also had much to do with the recent great increase of worms in this State. For the first two or three years after the question of residue came up most Missouri growers, even where they were prepared to wash the fruit, actually let up on spraying as the season advanced, hoping that they would control the worms and yet not be obliged to wash.

Other factors contributing to ineffective control work have been the shortage of working capital, inadequate spraying equipment, low prices for clean fruit, favorable opportunity to dispose of poorer grades and the generally depressed morale of growers even though, as a group, they have weathered the crisis as well or better than other agricultural groups. These and other factors which might be mentioned have now brought our growers face to face with the proposition of either controlling the codling moth or going out of the orchard business. Truly the apple growers are now fighting that next great war with one of their insect foes and a successful outcome is assured if they continue to use the best proven practices and materials and stand ready to turn to new and better ones as soon as they are proven to be better.

*This report is a summing up of the findings and results of experimental work on the control of the codling moth conducted during the past 20 years by the department of entomology. During that period assistance was given by the various department assistants and graduate students, especially A. H. Hollinger, K. C. Sullivan, O. C. McBride, Paul H. Johnson, Geo. D. Jones, V. F. Burk, Lee Jenkins, Chas. H. Bowen, R. L. Meffert and James Bailey. Former Director F. W. Faurot and R. M. Jones of the Missouri State Fruit Experiment Station and A. J. Ackerman of the federal laboratory at Bentonville, Arkansas, also assisted with the work. The cooperation of the department of horticulture, various county agricultural agents, fruit growers and insecticide firms is also acknowledged.

This report is an attempt to point out some fundamental facts about the pest which explain why it is difficult to control and to briefly summarize the results of recent experiments and methods which show promise of more effective control in the future. In most orchards the codling moth has been on the increase for the past several years and it is folly for the grower to expect to get complete control in one year. However, a carefully planned and properly timed spray program, supplemented with the elimination of the packing house hazard, scraping and banding, the destruction of wormy fruits and drops, and general orchard sanitation, should in a few seasons restore satisfactory control.

LIFE HISTORY

The caterpillars of the codling moth spend the winter in cocoons mostly beneath the loose bark on the apple tree, and in the packing house. These pupate about the time the apple trees bloom and in two or three weeks the spring or first-brood moths begin to emerge. Each female moth may lay from 100 to 150 eggs mostly on the foliage near the fruits. In about 7 to 10 days these eggs hatch and the small larvae enter the fruits. After feeding for about three weeks the larvae are full-fed. They then leave the fruit, find a place to spin their cocoons, pupate and soon begin to emerge as the second or July brood of moths. These also lay eggs which produce the July and early August brood of larvae. These become full-fed, leave the fruit, pupate and emerge as the third or August brood of moths. Their offspring are entering the fruit during late August and September as the third brood larvae. These survive the following winter and emerge in the spring as moths. The grower directs the May and June cover sprays at the first brood of worms, the July sprays at the second brood worms and the August sprays at the third brood worms. The broods overlap but there are waves of heavy emergence; therefore the grower, in timing his sprays, should know when these occur.

Weather has an important influence on the development of the codling moth. Mild winters and warm, dry summers favor rapid increase by insuring low winter mortality and rapid development in the summer, with abundant egg laying and conditions favorable for the worms to reach and enter fruits. On the other hand, very low winter temperatures may result in the death of a large percentage of the hibernating worms; while rainy, cool and windy weather during the egg-laying periods prevents rapid increase of worms.

Aside from natural control by unfavorable weather the grower must depend largely upon his own efforts to keep the pest under control. Parasites and diseases have failed to give much assistance and usually only in orchards near timber do insect-feeding birds, especially

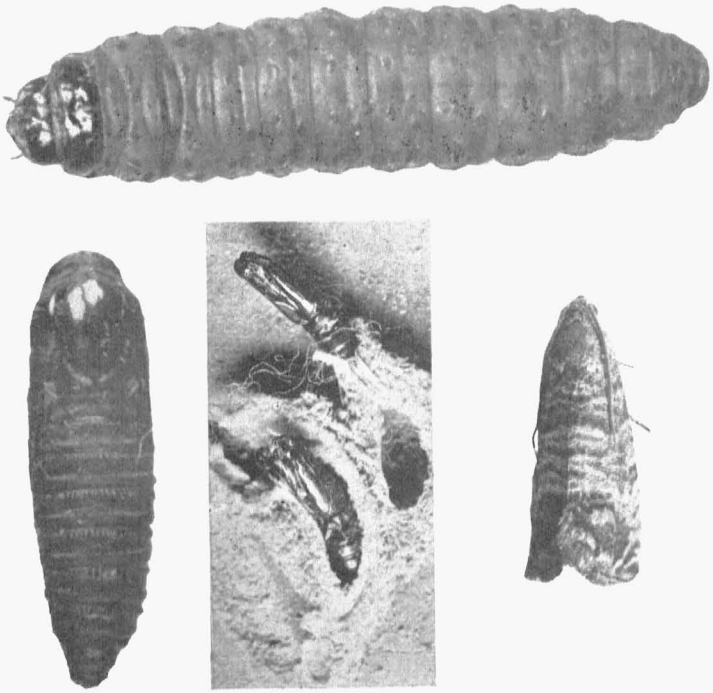

Fig. 2.—Codling Moth.—Larva, pupa, pupa cases in cocoons and adult. Enlarged from three to six times.

the hairy and downy woodpeckers, assist greatly. The codling moth, by nature, is quite well prepared to take care of itself and to provide abundant offspring. In its life cycle there are no periods or stages which are especially vulnerable to either natural or man-made controls, though the moth's seeming weakness for baits and certain lights may some day prove its downfall.

SPRAY CONTROL

Recent spray residue regulations have stimulated increased effort to find a satisfactory substitute for arsenate of lead. While arsenate of lead has its shortcomings and may even fail utterly to protect the fruit unless supplementary control measures are also used, it is still the most effective insecticide. In Missouri, we shall continue to recommend that our growers use arsenate of lead and prepare to remove excess residue by washing, until a satisfactory substitute spray is found.

For the past few years, therefore, in our spray investigations we have attempted to determine the most effective strength of arsenical spray solution or combinations of sprays and dates of application for best results. Where initial worm populations are exceptionally high

and where climatic conditions are favorable for optimum development of the pest, it is doubtful if any strength of arsenate of lead spray or combination of sprays and number of applications that can safely be applied will give satisfactory control without the help of supplementary measures. Our experimental results in four different heavily infested orchards in 1933 indicate that this is true. On the other hand, where worms are not abundant, arsenate of lead sprays have given perfect control.

Some fruit growers believe that in recent years arsenate of lead has either not been as strong as formerly, or else the apple worms have developed a tolerance for it. Some recent entomological investigations might lead growers to conclude that the pest in some sections of the country shows such tolerance. Codling moth larvae from different sections of the United States have been collected in the same laboratory, under identical conditions, and tested as to their ability to enter sprayed fruits. The resulting data indicated that worms from some sections were much more proficient than others. This was first taken as an indication that these particular strains of larvae were more resistant to the action of arsenic than were the others.

Investigations conducted by this department*, including these same strains of larvae, show that, when measured doses of either soluble arsenic or arsenate of lead are fed or administered by means of a hypodermic syringe directly into the digestive tract, there is no evidence whatever that one strain can consume more arsenic than the others. They may be more hardy and better able to sidestep the arsenic on fruit, but when it is fed to them they show no increased tolerance for it. Also careful determinations of the dosage of arsenic lethal to Missouri codling moth larvae do not indicate that in the past several years they have developed any increased tolerance for arsenic.

The difficulty which our growers have had in recent years in controlling the pest has not been due either to faulty insecticides or to larval resistance to arsenic. Rather it has been due to climatic conditions favorable for rapid increase of worm populations from year to year until now even the most drastic spray schedule is not sufficient to kill all larvae attempting to enter the fruit. Our only way out of this condition is to supplement spray control with other means of reducing worm populations.

How Sprays Kill Codling Moth Larvae.—It is difficult sometimes for a grower to understand why he has so much wormy and stung fruit after he has put on seven or eight sprays and has kept the foliage and fruit well covered all summer. There is much that we may still learn

*Missouri Agricultural Experiment Station Research Bulletin 202. Also Journal of Economic Entomology Vol. 22, p. 655.

about the habits and behavior of the codling moth but the few facts that are known about the newly hatched larvae help to explain why spray coverage does not give 100 per cent protection. In spite of perfect coverage with arsenate of lead and other poisons, many worms may cause stings before the poison takes effect and some will enter without being injured at all by the insecticide.

During the summer codling moth eggs usually hatch in from 5 to 7 days and the young active larvae set out at once in search of fruit to enter. When forced to do so, they may feed on foliage and soft twig growth, but very few survive in an orchard when there is a complete loss of the fruit crop. As the larva moves about it walks on a silk thread which it spins and attaches with each forward movement by touching its mouth to the surface on which it is traveling. On an oily surface and, to a less extent, on a wet surface, the larva has trouble attaching the silk thread.

The codling moth larva is a borer by nature and its first aim in life seems to be to dig a tunnel and to get away from the light, weather and enemies. It does not lose much time, therefore, in digging in once it chooses a place to enter. A silk net or carpet is quickly spun and it holds to this as it works frantically cutting out bits of peel and pulp in making an entrance tunnel. In the laboratory it requires an hour or more for the larva to dig its way into the fruit and, in doing so, it cuts and discards irregular-shaped bits of fruit peel and pulp. Some larvae, while entering, appear to eat very little of the material they bite out; others consume a great deal of it.

About one-third of the worms on unsprayed fruits, from our observations, enter directly through the calyx cup, which defends the contention that the calyx spray is of vital importance.

When we consider the rapidity with which the worms may enter the fruit and the fact that they may discard all or most of the cuttings in entering, it is easy to see why we do not kill all of them with poison sprays. Some of them undoubtedly take poison into their mouths while attaching their thread of silk to the poison-coated foliage and fruit. Some of them also swallow minute quantities of poison with food consumed while entering the fruit. Some of them may pick up poison on their feet and bodies as they travel over sprayed surfaces, carry it into the entrance pit and later consume it while feeding.

To be most effective the spray coverage must be renewed from time to time so that the fruit and foliage will remain thoroughly covered with a coating of poison which the larvae may pick up readily. Oil may kill by direct contact and, for a time, also prevent the larvae from traveling about, but by sealing the lead on the fruit and foliage, as our results would indicate, it may make it less available to the larvae. Nicotine and other similar insecticides give a quick kill for a short time but must be repeated often.

SPRAYING EXPERIMENTS AND WHAT THEY INDICATE

In 1933 the department of entomology conducted its spraying experiments in the Kenmoor Orchard at DeKalb, the C. E. Hitz orchard at Fortescue, the O. O. Harlan and H. L. Seneff orchards at Marionville, the State Fruit Experiment Station orchard at Mountain Grove, and in the Experiment Station orchard at Columbia. In the orchards at DeKalb and Fortescue worm populations had been high, scraping and banding had not been used as supplementary controls, and open packing sheds were close enough to the experimental blocks to complicate results.

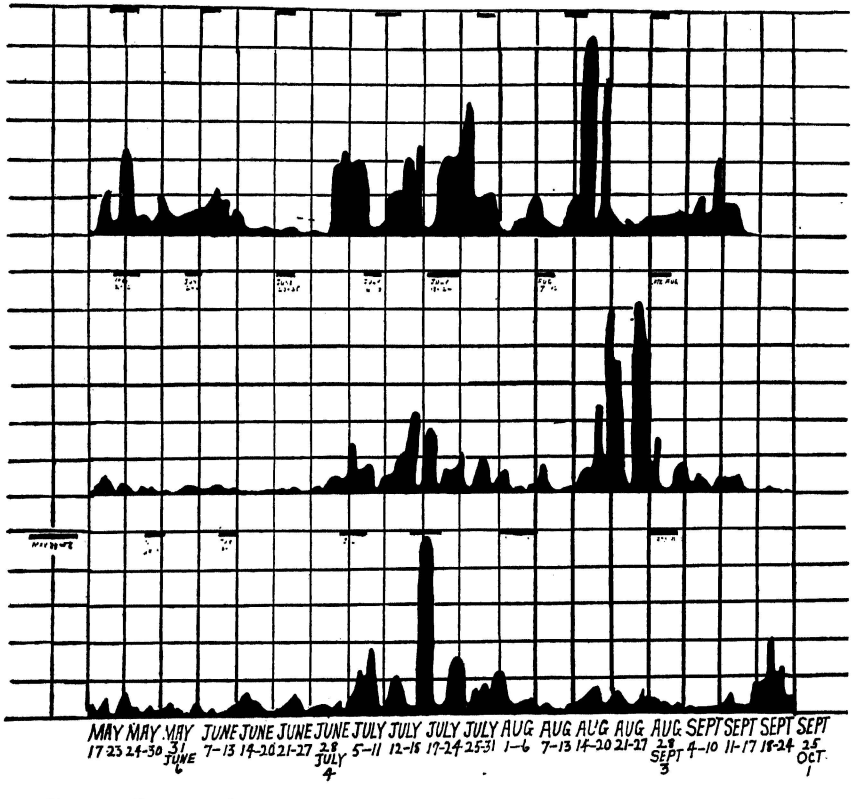

Fig. 3.—Record of codling moth abundance in 1933 as shown by catches in 12 bait traps at Marionville in bottom figure, in 28 at Columbia in central figure, and in 14 traps at St. Joseph in upper figure. Recommended dates for cover sprays shown by transverse dashes above each graph. Each vertical spacing represents 50 moths.

In the Marionville orchards initial worm populations were quite high, scraping and banding had not been regularly followed in the past, and packing sheds were not near the plats. In the State Fruit Experiment Station orchard worm populations had been variable but not

uniformly high and the packing house was not near. At Columbia the worm populations were moderately severe. In all the orchards rainfall for the summer was light, especially in the central and northern Missouri orchards. From five to nine experimental plats were included in each of the orchards. The purpose of the experiments was to determine: first, the dosage and the number and dates of application of arsenate of lead for best results; second, the increased effectiveness from the addition of oil emulsion with arsenate of lead; and, third, the comparative value of substitutes used with or in place of arsenate of lead.

North Missouri Plats.—In the northern Missouri experiments six uniform plats of Jonathan trees were used and six cover sprays besides the cluster and calyx sprays were applied. All plats received 2 pounds of arsenate of lead to 100 gallons in the cluster and calyx sprays. Plat 1 received a light dosage of arsenate of lead, including 2 pounds to 100 gallons in all cover sprays except the second when 3 pounds were used. Plat 2 received a heavier dosage of arsenate of lead, including 3 pounds to 100 gallons in the first cover, 4 in the second and third, 3 in the fourth and 2 in the fifth and sixth. The other four plats received a light dose of 2 pounds arsenate of lead plus summer oil emulsion or dormant oil emulsion in varying amounts. Plats 3 and 5 had 1% summer oil of two different brands added in the second and third cover sprays, Plat 4 had ¼% dormant oil in the second and third cover sprays, while Plat 6 had 1% summer oil added in the second, ¼% in the third, 1% in the fourth and had the fifth cover spray omitted. Plat 1 showed twice as much lead residue as the tolerance, Plat 2 showed two and one-half times as much as the tolerance, while those receiving light lead plus oil varied from three to nearly four times the tolerance.

The control of worms was not satisfactory in any of the plats in these two orchards. While the variation in effectiveness was not marked, all things considered, Plat 2 with the heavier arsenate of lead dosage ranked first at picking time, Plat 6 ranked second, Plat 1 third, Plats 3 and 5 fourth and fifth, and Plat 4 ranked sixth. On July 20, however, Plat 6 had the smallest per cent of sideworms, Plat 2 second, Plat 5 third, Plat 3 fourth, Plat 1 fifth and Plat 4 sixth. It should be pointed out that, when all the plats in the two orchards receiving arsenate of lead, to which summer oil was added in two or more of the important cover sprays at approximately 1% strength, are considered, the oil reduced the average percentage of stung fruit and slightly increased the per cent of perfects, but it did not reduce the percentage of wormy fruit.

The average of the results on picked fruit secured in these two orchards with the heavier dosage of arsenate of lead, with the lighter dosage and with the lighter dosage plus two applications of 1% summer oil in the first brood sprays are shown in the following table:

TABLE 1.—RESULTS ON NORTHERN MISSOURI PLATS

Plats	% Perfect	% with calyx worms	% with side-worms	S. worms per apple	% with stings	Stings per apple	% with curculio stings	Curculio stings per apple
Heavier ars. of lead	8.95	.73	54.98	1.24	79.6	1.97	3.73	.125
Light ars. of lead	10.23	2.6	58.25	1.76	73.65	2.12	2.8	.065
Light ars. of lead + two 1% oils	10.21	4.44	64.45	2.18	74.71	1.75	6.45	.068

Marionville Plats.—This experiment included six uniform plats of Gano trees in each of the two commercial orchards. The initial infestation was quite severe and uniform over the plats. Seven cover sprays besides the calyx and cluster bud sprays were applied and they were applied thoroughly. All the plats received 3 pounds of arsenate of lead to 100 gallons in the calyx spray but none in the cluster bud spray.

Plat 1 received a heavy dosage of arsenate of lead, including 4 pounds to 100 gallons in the first three cover sprays, 3 pounds in the next three, and 2 pounds to 100 gallons in the seventh cover spray. The other six plats received arsenate of lead and oil in combination. Plat 2 received the heavy lead dosage, the same as Plat 1, plus 1% summer oil in the second, third and fifth cover sprays and ¼% oil in the fourth, sixth and seventh. Plats 3 and 5 had the arsenate of lead reduced to 2 pounds to 100 gallons in the second and third cover sprays and had 1% summer oil of two different brands added in these two sprays. Plat 4 had the same treatment as Plat 1, except that the fifth, sixth and seventh sprays included 1% summer oil in place of arsenate of lead. Plat 6 received the same heavy dosage of arsenate of lead and oil as in Plat 2, except that the fourth and sixth cover sprays were omitted.

In every case the dosage was heavy and theoretically satisfactory control should have been secured on each plat. Such was not the case, however, for while the percentages of wormy fruits were far less than in the North Missouri experiment they were too high and the percentage of stung fruits was very high. Tests for residue at picking time showed that Plat 1 had over twice the lead tolerance and over four times the arsenical tolerance, Plat 2 had four times the lead and five times the arsenical tolerance, Plat 3 had the same as Plat 1, Plat 4 two times the lead and two and one-half times the arsenical tolerance, Plat 5 three times the lead and five times the arsenical tolerance and Plat 6 had over

two times the lead and five times the arsenical tolerance. Special washing, however, should take care of such excesses.

The control of worms and stings was not satisfactory in any of these plats. In contrast with the North Missouri results here we had higher percentages of stings but lower percentages of worm entrances, indicating that the heavier doses killed more worms as they attempted to enter. While the differences were not striking, all things considered, when the results in the two orchards were averaged Plat 2 ranked first, Plat 3 second, Plats 1, 5 and 6 had about equal claim for third place, and Plat 4 ranked last. On June 19 following the third cover spray Plats 2 and 6 ranked first, Plat 5 second, Plat 3 third, and Plats 1 and 4 fourth with an average of 4.6% of the fruits wormy. Where oil was used after the first of July it reduced the stings but not the percentages of fruits with worms entering. The increased dosage of arsenate of lead in the lead-oil combination and the increased number of cover sprays which had oil with lead did not materially affect the average percentage of fruits with stings or worms. From the results in these two orchards it would seem that, if oil is to be used with arsenate of lead, not more than three 1% applications, two for first brood and one for second brood worms, should be made. Also, where worm populations are as large as in these orchards the dosage of arsenate of lead should be 3 to 4 pounds to 100 gallons in the first brood sprays and 3 pounds dropping to 2 pounds in the later sprays. The following table shows the average results on picked fruit where heavy dosages of lead were used alone and where arsenate of lead plus two or more applications of oil were used.

TABLE 2.—RESULTS ON THE MARIONVILLE PLATS

Plats	% Perfect	% with Calyx worms	% with S. worms	S. worms per apple	% with stings	Stings per apple	% Drops
Heavy ars. of lead	7.2	.86	24.4	.39	92.2	3.49	26.05
Ars. of lead + oil	13.1	.43	24.1	.4	86.3	3.16	27.5
Check	17.5	.5	71.6		19.2		90.04

Mountain Grove Experiment.—The first six test plats in this experiment received the same spray schedules as those at Marionville. Plat 7 received 4 pounds arsenate of lead to 100 gallons in the first three cover sprays and 1 gallon summer oil and 1 pint nicotine sulphate to 100 gallons in the July and August sprays, Plat 8 received 3 pounds, and Plat 9 received 2 pounds calcium arsenate to 100 gallons beginning with the second cover. The initial worm population was much lower than in either the Marionville or the North Missouri plats and the control

was much more satisfactory. The following table shows the results on picked fruits secured in this experiment.

TABLE 3.—RESULTS OF MOUNTAIN GROVE EXPERIMENT

Plat	% Perfect	% Wormy	% Calyx Worms	% Sideworms	% Stings
I	81.9	1.2	.1	1.12	17.8
II	81.4	4.7	.15	4.6	14.8
III	72.9	10.7	.3	10.4	18.6
IV	81.5	3.6	.3	3.4	15.4
V	75.2	5.26	.7	4.7	20.5
VI	80.8	3.3	.3	3.2	16.2
VII	73.5	11.9	2.06	11.3	21.6
VIII	54.1	9.48	.4	9.48	39.5
IX	60.3	14.3	.4	14.1	28.4

It seems evident from a review of the results of these experiments that, under Missouri conditions, where initial worm populations are small, a regular spray schedule of either arsenate of lead, or arsenate of lead plus oil, in some of the cover sprays will keep the codling moth under satisfactory control. On the other hand, where initial worm populations are high and breeding conditions are favorable a heavy spray schedule of arsenate of lead, or arsenate of lead plus oil, may fail to bring the infestation under control in one season, even where supplementary controls are used. For the immediate future we would recommend that where worm populations are high the spray schedule include 2 or 3 pounds of arsenate of lead in the calyx spray, 3 or 4 pounds in, at least, three first brood sprays with oil in the last two, 3 pounds in two July sprays, and 2 pounds to 100 gallons in two August sprays together with fungicides as needed.

TIMING THE SPRAYS

From what has been said about the life cycle of the codling moth, it is evident to everyone that there are periods throughout the summer when worms are entering the fruit in greatest numbers, and at such periods there is greatest need for thorough spray coverage. In order to keep the fruit growers informed as to moth and worm activity, the department of entomology for several years has been maintaining breeding stations in all of the important apple growing regions in the State. Daily records on first brood moth emergence and later band and bait pan records enable us to determine for each region the periods when worms in greatest numbers are entering the fruit. With this information the grower can time his various cover sprays so that he may control the worms of the different broods to best advantage. The time-to-spray recommendations sent to all growers throughout the summer are based on these daily records for the region in question and, while each orchard

is an individual problem, these records and recommendations will prove helpful as a guide to the growers. Each grower must modify them to meet the conditions which obtain in his orchard.

SUPPLEMENTARY CONTROLS

It is now quite generally agreed that supplementary controls are indispensable in seasons favorable for codling moth increase and in orchards where large initial moth populations occur. With this in mind, we have been studying the effectiveness of the various supplementary controls for the past several years. We have found that scraping and banding, moth-proofing the packing shed if located in the orchard, treating or storing used equipment so escaping moths do not get back into the orchard, picking and disposing of wormy fruits, drops and culls and complete orchard sanitation are the most economical and effective supplementary controls for codling moth.

Scraping and Banding.—Where spray control has not been satisfactory and especially where the trees are old and carry scaly bark, each tree should be carefully scraped during the winter or early spring preparatory to banding in June. A sharp, short-handled hoe, a meat block scraper, or an improvised scraper made from a leaf of buggy or car spring will serve the purpose. Remove all the scaly bark from the trunk, crotches and main limbs as high as it is convenient to reach, catching it on a canvas spread about the base of the tree and later destroy it. Deep crotches, rough pruning scars and decayed places should be carefully cleaned out and treated with one of the new pine tar distillates or with a good coat of disinfectant paint. To scrape a large tree properly requires some time but it pays well in the immediate destruction of many worms and in the elimination of cocooning places for worms later, thus forcing them to enter the bands.

The grower may use either treated bands or untreated bands, but in the latter case he must take them off once a week during the summer and destroy the worms. In case untreated bands are used, folded strips of burlap or six-inch strips of tar roofing paper with an inch fold turned in at the top work very well. Unless cheap labor is available, it is more economical to use chemically treated corrugated paper bands. These may be purchased treated ready to apply, or the corrugated paper and the chemicals may be purchased and the bands dipped at home.

The beta naphthol is now available either in paste form or in finely ground dry form for use in treating bands at home. If the standard paste is used, dilute it at the rate of 2 pounds to each pint of gasoline. If the dry beta naphthol is used, first mix it at the rate of 1 pound to 1½ pints of cheap lubricating oil of 150 to 200 viscosity and then use 2 pounds of this paste to 1 pint of gasoline. Use a tub or similar container

and keep the mixture well agitated while dipping the flat rolls of corrugated paper. Dip either for 30 to 60 seconds or for a shorter time and turn the rolls over and dip again with the other side down. Two pounds of beta naphthol in the dipping solution will treat 50 feet of 4-inch bands or about twice that length of the 2-inch bands. Protect the hands while dipping and handling the bands. It is cheaper to treat bands at home, but if one does not have the time to do it right it is more desirable to buy the treated bands. Those who wish to treat their bands should write to the Experiment Station for specific directions and the sources and prices of the materials.

In a normal season the bands should be put on the trees about June 10 to 15. Long, flat-headed tacks may be used to fit the bands snugly around the tree trunk and in the depressions. They must be fitted tight against the tree if they are to catch the most worms. (CAUTION: Do not use them on young trees or those which still have smooth bark, as they may seriously injure the trees by killing the bark beneath the band.) Leave the treated bands on until the following December and then remove and burn them to destroy any worms which may be alive in them at that time.

Fig. 4.—Apple tree with 2-inch chemically-treated corrugated paper band and homemade breeding cage. Every grower who has a serious codling moth problem should band his trees and use a breeding cage to follow moth emergence.

Efficiency of Bands.—While our observations indicate that for every three worm entrances in fallen and picked fruits the bands account for only one worm, we consider banding a very effective supplementary control. It is not known what becomes of the rest of the worms but probably many fail to mature and others are destroyed before they find the bands. Careful examination of numerous trees with varying types of ground litter indicate that about 87% of all larvae which spin up on or under a tree actually enter the treated bands. The remainder spin up elsewhere on the tree or in ground litter. Of the worms entering properly treated bands not more than from 1 to 3 per cent emerge as moths. For us the 2-inch bands catch about the same number of worms on the average as bands 4 inches wide and they cost considerably less. We usually get from 200 to 300 worms to the band on large trees in

heavily infested orchards though we have taken over 1300 worms in a single band. Thus far we have found that the commercial hot-dipped and the homemade cold-dipped bands when properly treated are about equally effective in killing worms. Larvae which enter the bands late in the fall may still be alive when the bands are removed but they are destroyed with the bands. No other orchard practice destroys so many worms and at such low cost, five to eight cents per tree, as do chemically treated bands.

Moth-proof the Packing House.—For years growers have realized that the trees near the packing house have had more worms than the rest of the orchard. The codling moth is capable of flying a considerable distance but in the orchard it is believed that they usually lay most of their eggs on the same tree from which they emerge or on those of the first four to six adjoining rows. However, with each succeeding brood of moths the spread from the packing house may be greatly increased during the summer and fall. An open packing house in the orchard is a real menace, therefore, and should be either moth-proofed or moved at least a quarter of a mile and preferably a mile or more from the orchard. The hundreds and thousands of bushels of apples which may be brought to the packing house for washing, grading and perhaps storing for a time will give off thousands or tens of thousands of larvae, many of which find cocooning places in the barrels, boxes and other containers or in protected places about the house. Growers who have moth-proofed their houses and then systematically destroyed and counted moths during the early summer emerging period have reported thousands of moths besides many which have died without being counted. In some houses where coal oil or fly spray was used to kill them as they collected about windows, we have seen the floor carpeted with dead moths. In such cases, the grower, at slight cost, eliminates hundreds of thousands of future worms.

The packing house or shed should not only be moth-proofed but the used equipment should either be kept in the house until after spring moth emergence is over or else it should be treated by dipping in a tank of coal oil or in water kept near the boiling point to destroy the cocooned worms. In case the packing house is a reasonably tight building, such as a barn, it is a simple matter to close cracks and other openings and thus moth-proof it. If it is an open shed the problem is much more difficult. Removable sections of light timber or rain-proof pressed board may be used to close the openings until after all spring moths have emerged. Some prefer to use screen or cloth to close such openings. If the building is darkened and provided with one or two small glass sashes or windows on the south or west side, the moths will collect on them where they can be killed each evening with some cheap spray. If the

building is elevated, care should be taken to prevent moths from escaping in great numbers from beneath the floor. A little labor and expense in preventing moths from escaping from the packing house and from used containers will help to prevent much wormy fruit, especially in that part of the orchard.

Pick Wormy Fruits and Dispose of Drops and Wormy Culls.—The cleanest crop of apples produced in any mature orchard in Missouri in 1933 received only the cluster, calyx and three first brood cover sprays. A crew was kept busy picking wormy fruit and disposing of all drops, and the orchard was kept cultivated throughout the summer. Climatic conditions undoubtedly played some part in this orchard, but the early sprays and systematic destruction of wormy fruits resulted in an almost 100% clean crop of fruit. It costs considerable to pick and destroy wormy fruits and drops, but in this case the results were far better than in any of the regularly sprayed orchards. In our sprayed plats 60 per cent of the drops were wormy, and in our unsprayed check plats 98 per cent of the drops were wormy. The systematic gathering of the wormy drops and the picking and destroying of wormy fruits, therefore, will eliminate a majority of the worms of each brood and thereby increase the effectiveness of the sprays. By leaving the ground strewn with wormy drops throughout the summer and with piles of culls scattered about the orchard and packing house, the grower gives the pest an opportunity to build up its populations with each succeeding brood. Picking wormy fruits and the destroying of wormy drops and culls should be used to supplement spray control and not to take the place of it.

Orchard Clean-up and Cultivation.—While our study of the distribution of the cocooned worms on and in ground litter under apple trees indicates that less than 5 per cent of the worms spin up in the ground litter, we feel that general orchard clean-up work to remove litter such as rags, paper, sticks, etc., will eliminate considerable numbers of worms in badly infested orchards or force them to use the tree bands for cocooning. The type of ground litter and the severity of the infestation in the orchard will determine the numbers of worms eliminated by such clean-up work. Also, where the land and age of trees will permit, disking under and between the trees will help still further in eliminating many worms and in improving soil fertility. Where worms are not serious and the orchard has had good care further clean-up work may be unnecessary and in old orchards and where soil washes the grower will naturally not cultivate.