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Codling Moth Control in Idaho

By

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THE residue problem is necessitating a constantly changing codling moth spray program. This Bulletin has been prepared for Idaho apple growers who need a concise knowledge of codling moth life history and control. The control program here recommended is based on extensive experimental work in the State. The authors appreciate fully that satisfactory substitutes for lead arsenate may become available or that, if tolerances are still further lowered, substitutes not entirely satisfactory may have to be used. However, the spray program outlined will be essentially the same if other insecticides are used in place of lead arsenate.

Codling Moth Control In Idaho

By Claude Wakeland and R. W. Haegele*

THE chief factors in profitable apple production in Idaho are the market price of the fruit, the codling moth, and the residue problem. Given a reasonable price and a high degree of control of the codling moth, the grower may expect to continue producing profitable apple crops which are free from objectionable residues. Lacking a high degree of control he has little chance to make a profit even during years of high prices. Improvements and economies must be based on a thorough knowledge of the insect's life history and habits under different seasonal conditions. Studies were conducted for three years to ascertain knowledge of the life history and habits of the codling moth in southwestern Idaho and the results have been published in detail.[1]

The Idaho Agricultural Experiment Station has conducted codling moth control experiments in southwestern Idahó for a period of five years. These experiments were based on the life history studies mentioned, and it is the purpose of this Bulletin to present the results of the experiments in a form that will be helpful to the practical grower. Experiments were conducted in southwestern Idaho because that section contains the largest apple-producing district in the State. Southwestern Idaho, as considered here, includes all of the apple-growing districts in Ada, Canyon, Gem, Payette, and Washington counties. Findings are quite closely applicable to the Lewiston district because of the close similarity of climate in the two districts. In a lesser degree, perhaps, this holds true for the Hagerman Valley and Twin Falls districts.

Conditions are changing, resulting in a constantly changing problem of codling moth control. It was a simple matter in the early days of apple production to control this insect when the infestations were light and the tree plantings young and scattered. It is quite another problem now when orchards are close together, trees are big, and the codling moth population is large. In every community there are at least a few growers who have little interest in orcharding or do not make any serious attempt to understand the habits of the codling moth and it is inevitable that the moth population remains high in spite of the splendid work in control which is practiced by interested orchardists.

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[1] Codling Moth Life History in Southwestern Idaho. Idaho Agri. Exp. Sta. Res. Bull. No. 10. 1932.

Lead arsenate is far from being an ideal insecticide for codling moth control, but to date it is the best one known, considering factors of safety to fruit and foliage, economy and degree of kill of codling moth worms. Owing to its slowness of kill, many larvae which eventually die before they can cause "wormy apples," live long enough to produce stings which reduce the market value of the fruit. Lead arsenate is further objectionable due to the fact that a deposit of it on the fruit is considered by the Food and Drug Administration, United States Department of Agriculture, deleterious to human health. The United States Government has deemed it advisable, therefore, to bar from market, fruits that contain dangerous amounts of such spray residue. This ruling has resulted in an extensive amount of experimentation in many states in an attempt to find a desirable substitute, the use of solvents to remove the residue, and the use of machines for commercial washing. With our present knowledge it is better practice to use lead arsenate as freely as necessary to secure codling moth control and to remove the residue after harvest than to depend on substitutes.

Summer oil added to certain of the lead arsenate cover sprays has come into extensive use in Idaho and has been proven to increase materially the degree of control. The chief objection to the use of oils with lead arsenate is that they increase the difficulty of residue removal. Extensive investigations by the Department of Agricultural Chemistry, Idaho Agricultural Experiment Station,[2] have shown that when oil sprays are used in accordance with recommendations in this Bulletin, residue can be removed by commercial washing. The value of oil as an insecticide lies in the fact that it kills codling moth eggs although it must be applied at just the right time to cover the maximum number of the eggs.

THOROUGHNESS AND TIMELINESS IN SPRAYING

Let it be borne in mind that it is practically impossible completely to cover all of the fruit and foliage on a large apple tree. The greatest single difficulty in codling moth control in Idaho today probably is the lack of thoroughness in spraying. Many who pride themselves on their thoroughness may be suffering from a delusion and should check on their own work by climbing into a tree occasionally and making a critical examination. While it is highly desirable to have good equipment and to keep it in first class running condition, such equipment will avail little unless the operator takes extreme care to be thorough in his work. There is ample evidence that good control is being accomplished in some of the badly infested districts of the State with rather poor equipment by men who are satisfied with nothing less than positive, complete coverage.

[2] The Removal of Arsenical Residue from Apples, Idaho Agricultural Experiment Station, Bulletin 187, November, 1931.

Thorough spraying is much easier and more quickly done when a pressure of at least 350 pounds is maintained. Particular attention must be given to spraying the upper portions of the trees and it is physically impossible to cover the tops without good pressure and ample volume of liquid.

One of the chief factors responsible for continuous high populations of the codling moth in Idaho is the lack of satisfactory spraying equipment. Many of the machines in use are obsolete and there are far too few machines of all types to insure completing the sprays soon enough to have them timed correctly. This fact applies to many of the better orchardists as well as to the careless ones. Equipment should be sufficient to enable an orchardist to complete any given spray within three to four days. Frequently a single spray machine is depended on for spraying 80 or more acres of apples, and the result is that most of the spraying is not done at the right time. Another factor responsible for high populations of the codling moth is that many small growers depend on custom spraying. Obviously, custom spraying cannot be very effective in control, regardless of the integrity of the man doing the spraying. His profit depends on volume of business and he must keep his machine busy. His services often are not available at just the time sprays are the most effective and frequently no attempt is made by the grower or the operator to apply sprays at the most advantageous times.

Timeliness is equally as important as thoroughness. One spray application which is made two or three days too late may result in a high degree of worminess even though all of the other applications are timed correctly. This is especially true of sprays intended to be applied at the peaks of the larvae. During some seasons, the majority of the first brood eggs hatch over a very short period of time. At that time, a spray timed only two or three days late may allow enormous numbers of larvae to enter the fruit. These would produce adults which would be progenitors of larvae that would attack the apples again in July or August, a time when it is extremely difficult to obtain control by spraying. When using the spray of oil and lead arsenate, the ideal time for effectiveness is to apply it just before the peak of egg-hatching, killing the eggs present at that time and leaving a deposit of lead arsenate on the fruit which will kill larvae that escape the oil or that hatch from eggs deposited after the oil was applied.

EXPLANATION OF TERMS USED

Growers need to have a knowledge of the terms used in order to understand the discussion of life history and control practices. A brief explanation of terms used in this bulletin follows:

The term "stage" refers to each of the four distinct periods of development through which the codling moth passes; namely, egg, larvae, pupa, and moth.

A "generation" begins with the egg stage of an individual or a group of individuals and terminates with the moth stage. The first generation begins with the first eggs laid in the spring and the second and third generations follow in succession. The "overwintering generation" includes all individuals of any generation which pass through the winter before transforming.

The term "brood" is used in speaking of individuals of any stage of a specific generation. The terms "first-brood", "second-brood," etc., when applied to eggs, larvae, pupae, and moths, designate the generation to which these stages belong. Pupae and moths which develop from overwintering-brood larvae are called "spring-brood pupae" and "spring-brood moths."

The "life cycle" includes the time from the deposition of the egg to the emergence of the moth of the same generation.

"Transforming larvae" are those that transform to pupae and moths the same season they hatch while "non-transforming larvae" are those that do not make this change until the following spring.

The "cocooning period" is that portion of the larval stage between emergence from the apple and pupation.

The successive stages of development of the codling moth in southwestern Idaho are as follows:

1. Overwintering-brood larvae.
2. Spring-brood pupae.
3. Spring-brood moths (growers commonly call these "first-brood moths").

First Generation:

1. First-brood eggs.
2. First-brood larvae.
3. First-brood pupae.
4. First-brood moths.

Second Generation:

1. Second-brood eggs.
2. Second-brood larvae.
3. Second-brood pupae.
4. Second-brood moths.

Third Generation:

1. Third-brood eggs.
2. Third-brood larvae.

(Nearly all these are non-transforming larvae).

APPEARANCE AND HABITS OF THE CODLING MOTH

The Moth. Bait traps, used for timing spray applications, have come into such general use that most orchardists have become familiar with the adult insect caught in the traps. Prior to the use of traps, however, the majority of orchardists had never seen a codling moth, even though they may have sprayed for years to control it. Adults rest quietly on foliage during the daytime and are very seldom seen or recognized. They are most active at dusk on warm evenings. When at rest the wings are folded backward over the body. The wings vary in color from a golden brown to light gray or occasionally very dark gray, crossed with darker or with lighter gray lines and near the tip of each front wing is an irregular golden spot. The wing expanse varies from five eighths to three quarters of an inch.

Moths feed very little and begin depositing eggs from two to four days after they emerge, if the weather is favorable. Nearly all of the eggs are deposited at dusk and only when the temperature is 60° F. or higher. The number of eggs deposited by individual females and by the moths of the different generations varies greatly. In the studies mentioned the number of eggs varied from a very few to 241 per female moth. For the three-year period the average number of eggs deposited per female moth was 57, 102, and 120 for spring-brood, first-brood, and second-brood moths respectively. Eggs are deposited singly. Early in the season most of them are placed on the upper surfaces of leaves near the fruit but later many are deposited on the fruit.

The Egg. The egg is quite flat and nearly circular in outline, the diameter being considerably less than that of an ordinary pinhead. When first deposited it is nearly transparent or of pearly-white color, but, as incubation progresses, a red ring, an early embryonic stage of the developing larva, sometimes becomes visible through the shell and, one day before hatching, the dark head of the larva is readily seen.

The Larva. The larva is light pink or cream-colored when it first emerges from the egg and has a brown head appearing proportionately very large. It is about one-sixteenth of an inch long. Larvae make their way out of the shell and crawl around over the foliage and fruit until a suitable place for entrance is found. They never eat into the fruit beneath the egg shell. They usually make an early entrance into the fruit but may crawl around on leaves and fruit for several hours. It is easier for them to gain entrance at rough places on the fruit, at points where an apple touches a twig or another apple, or through the calyx. Larva cast aside the skin of the apple when burrowing into the fruit, a fact that has an important bearing on codling moth control by the use of poisons. A large percentage of larvae enter unsprayed apples through the calyx.

Young larvae feed for a few days near the surface of the fruit or in the calyx cavity before burrowing into the center of the fruit, where they remain feeding on the seeds and pulp until maturity. Fully grown larvae make their way to the surface of the fruit through an exit tunnel from which they leave the fruit to seek pupating quarters. Mature larvae are about three-fourths of an inch long and vary from deep pink to cream-colored.

The Cocoon and Pupa. Larvae construct a tough cocoon of white, silken threads and bits of bark and wood within which they transform to moths. Cocoons of overwintering larvae are much heavier than those of transforming larvae and afford a much greater degree of protection. Cocoons are spun in any convenient location, the choice of the larvae being under loose bark, in tree crotches, under trash, in packing sheds, in crevices in picking and packing boxes, and, to a limited extent, in soil cracks near the bases of trees. Larvae, especially overwintering ones, may move and build new cocoons before pupation is begun. Immediately before pupation, they remodel their cocoons by building a small exit tube to insure exit of the moth.

The transformation stage within the cocoon is known as the pupa. Pupae are at first light yellowish-brown in color, become darker with the lapse of time, until just before the moths emerge they are mahogany brown. Before the adult emerges, the pupa wriggles its way outward until it protrudes beyond the mouth of the exit tube, the pupal case splits in front and the moth emerges, usually leaving its empty pupal case projecting from the cocoon.

SEASONAL HISTORY AND LIFE CYCLE [3]

Overwintering larvae. The larva or worm is the overwintering form of the codling moth. Overwintering larvae are non-transforming larvae of the first, second, or third generation. Only about 1½ per cent of the larvae of the first generation, most of the second generation larvae, and sometimes part of the third generation larvae are non-transforming.

Spring-brood pupae. Overwintering larvae change to spring-brood pupae with the advent of warm spring weather. The average duration of the pupal stage of the spring brood in southwestern Idaho is 24 days. The date the first larva pupates varies with the season from April 1 to April 7.

Spring-brood moths. Moths of this brood are commonly called by the growers "first-brood moths." The date of the first emergence of spring-brood moths varies with the season from April 29 to May 15 in southwestern Idaho. The seasonal variation in the duration of emergence is from 35 to 49 days. The seasonal variation in the height of spring-brood moth activity is from May 14 to May 26. The average length of life of spring-brood moths was found to be nearly 17 days.

First Generation

First-Brood Eggs. The seasonal variation in the date of deposition of the first eggs is from May 2 to May 22, and of the last first-brood eggs from June 27 to July 7. The seasonal variation in the height of egg deposition is from May 27 to June 8. The average duration of the egg stage is a little over eight days.

First-Brood Larvae. The seasonal variation in the date of appearance of the first larvae is from May 16 to June 7, and of the last first-brood larvae from June 26 to July 7. The seasonal variation in the height of larval emergence is from June 1 to June 16. The average feeding period of the larvae in the fruit is 22 days, the extremes being 12 days and 40 days.

First-Brood Pupae. The seasonal variation in the date the first larvae of the first brood transform to pupae is from June 11 to June 29, and of the last larvae of the second brood is from August

3 Specific statements concerning life history discussed in this bulletin are based on the data in Research Bulletin 10, Idaho Agricultural Experiment Station.

7 to August 25. The seasonal variation in the height of pupation is from June 26 to July 31. The average duration of the pupal stage is a little over 11 days.

First-Brood Moths. Moths of this brood are commonly spoken of by the growers as "second-brood moths." The seasonal variation in the date of the first emergence of first-brood moths is from June 23 to July 11, and of the last emergence from August 7 to September 7. The seasonal variation in the height of moth emergence of this brood is from July 4 to August 3. The average length of life of the moths is a little over 11 days.

Life Cycle of the First Generation. The average length of the life cycle of the first generation is nearly 47 days and the life cycle of individual moths varies from 37 days to 96 days.

Second Generation

Second-Brood Eggs. The seasonal variation in the date of deposition of the first eggs by second-brood moths is from July 1 to July 16, and of the last eggs from August 29 to September 10. The seasonal variation in the height of egg deposition is from July 14 to August 7. The average duration of the egg stage is a little more than six days.

Second-Brood Larvae. The seasonal variation in the date of the appearance of the first larvae of the second brood is from July 6 to July 22, and of the last larvae from August 10 to September 1. The seasonal variation in the height of larval emergence is from July 19 to August 13. Larvae feed in the fruit from 13 to 50 days, or nearly 23 days on the average.

Cocooning Period, Second Brood. The cocooning period of second-generation larvae occupies from 3 to 20 days, the average being a little over six days.

Second-Brood Pupae. The seasonal variation in the date the first larvae of the second brood transform to pupae is from July 25 to August 10, and of last pupation from September 6 to September 18. The seasonal variation in the height of pupation varies with the season from August 5 to August 19. The average duration of the pupal stage is a little more than 13 days.

Second-Brood Moths The seasonal variation in the date of the first emergence of second-brood moths is from August 4 to August 31, and of the last emergence from September 5 to October 3. The seasonal variation in the height of moth emergence varies with the season from August 16 to August 29. The average length of life of the moths is a little under 17 days.

Life Cycle of the Second Generation. The average length of the life cycle of the second generation is nearly 43 days, and the life cycle of individuals varies from 34 to 68 days.

Third Generation

Third-Brood Eggs. The seasonal variation in the date of deposition of the first third-brood eggs is from August 10 to September 7, and of the last of the eggs from September 17 to October 3.

The seasonal variation in the height of egg deposition is from August 26 to September 29. The average duration of the egg stage is 11 days.

Third-Brood Larvae. The seasonal variation in the date of emergence of the first third-brood larvae is from August 17 to September 17, and of the last larvae from September 28 to October 18. The seasonal variation in the height of larval emergence is from September 5 to September 20. During some years there are very few third-brood larvae, but in abnormally early seasons they emerge and enter the fruit in large numbers, thus accounting for the tiny larvae which frequently puzzle growers at harvest time.

Third-Brood Pupae. Most of the third-brood larvae are in the apples at harvest time and very few of them reach maturity even in apples left on the tree, so the percentage transforming to pupae is slight.

Fourth Generation

Life history studies indicate that it may be possible for the codling moth to develop to the fourth generation in Idaho, but that the occurrence is so extremely rare as to have no bearing on control practices.

Irregularities in Development

It should become clear to the orchardist, after studying the above summary of the codling moth life history studies, that spray applications must be timed by knowledge of the activity of the codling moth each year in each locality. Certain activities of the moth may vary as much as three weeks between one year and another. Obviously, spray applications timed correctly one season are likely to be entirely wrong the following season, if calendar dates are followed. A small amount of study on the part of the grower throughout each season will give him the information that he must have if he expects to time his sprays correctly and apply them economically.

CONTROL PRACTICES

Timing Spray Applications

Bait Traps. The best means now known to ascertain the activity of the moths and to properly time spray applications is by the use of codling moth bait traps well located in the orchard. One of these traps consists essentially of a small open granite pan about six inches in diameter filled with bait and suspended in an apple tree. Moths are attracted to the pan by the bait ferment in which they drown, and daily observations of the traps furnish the orchardist information enabling him to know definitely when moths of a certain brood begin emerging and when the peak of emergence occurs. Having this information he can plan intelligently when to make spray applications to greatest advantage. The bait that has given best results in Idaho is prepared by mixing together water, yeast, and dimalt in the following proportions:

Dimalt (malt syrup if dimalt is not available)	½ pint.
Water	5 quarts.
Compressed yeast	¼ cake

Keep this bait in glass or porcelain containers before using as the acid formed by fermentation will destroy metals and spoil

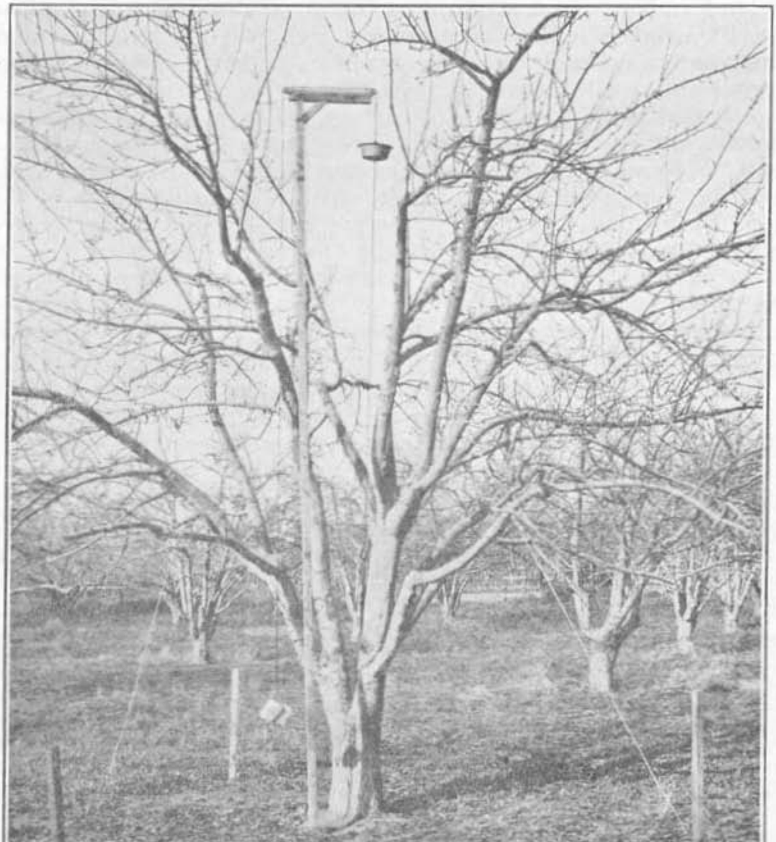

Fig. 1.—A useful scaffold for supporting bait traps. The lumber is 2"x2". Swaying of the trap is prevented by the guy wires. The weight suspended at the end of the cord extending over the pulleys on top of the scaffold holds the pan in a rigid position. The advantages of such an arrangement are: Accuracy of records; ease of operation; freedom from spilling the liquid by wind or by swaying of branches; and economy of time. Scaffolds will last for many years if stored and protected when not in use in the orchard.

the bait. Allow the bait to set about a day before using it so that fermentation will start, for it is the fermented liquid that is attractive to the moths. Prepare only sufficient bait at one time to refill the traps two or three times in order that only fresh bait may be used.

Traps should be placed near the tops of the trees and should be in place in the spring a week before the time of the calyx spray. They may be suspended by a cord run over a branch or through a screw-eye and may be raised and lowered by fastening one end to the tree within reach of the ground; or they may be suspended from a scaffold as shown in the illustration, (Fig. 1). By using a scaffold and pulleys and a weight as illustrated, information is much more accurate for the bait is seldom spilled out of the pan by wind, as so frequently occurs when traps are suspended from tree limbs. Scaffolds may be stored when not needed and will last for several years. Traps should be examined early each morning, the moths caught the night before removed, and the pans refilled with bait to within about one inch of the top. By keeping a record of the moths captured each day the grower may tabulate his data in a manner shown in this Bulletin (See Fig. 2) and have an accurate picture of the conditions as they develop from day to day. Many kinds of moths are caught in bait traps so the grower must be able to recognize codling moths if he is to be sure of his information.

Calyx Spray. The calyx spray is of great importance and although it may be applied several days or weeks before any eggs hatch, it remains effective in preventing worm entrance through the calyx. It is most effective, easiest applied, and less likely to injure bees if spraying is done when about 90 per cent of the petals have fallen. It must be completed on all varieties before the calyx lobes close up and the grower can well afford to time his calyx spray to suit each variety.

RECORDED DATES OF THE CALYX SPRAY

District	1923	1924	1929	1930	1931	1932
Coeur d'Alene	May 20	May 14	May 28	May 20	May 25	June ?
Lewiston	May 15	May 8	May 25	May 8	May 16	May 12
Weiser	May 15		May 17	May 6	May 16	May 19
Payette	May 15	May 9	May 25	May 6	May 16	May 19
Fruitland	May 15	May 10	May 25	May 8	May 16	May 19
New Plymouth	May 15	May 10	May 25	May 8	May 15	May 19
Emmett	May 10	May 5	May 14	May 6	May 10	May 15
Nampa	May 19	May 12	May 15	Apr. 28	May 16	May 16
Boise	May 10		May 25	May 13	May 15	May 16
Parma	May 10	May 9	May 17	May 5	May 13	May 12
Twin Falls			May 20	May 10	May 10	May 20

The above record kept by State Horticultural Inspectors and furnished through the courtesy of the State Department of Agriculture indicates that there is a variation of as much as 21 days between the date of the calyx spray in different seasons in the same locality.

Cover Sprays. Cover sprays may be almost or entirely wasted if they are applied at a time when moth activity is low in the

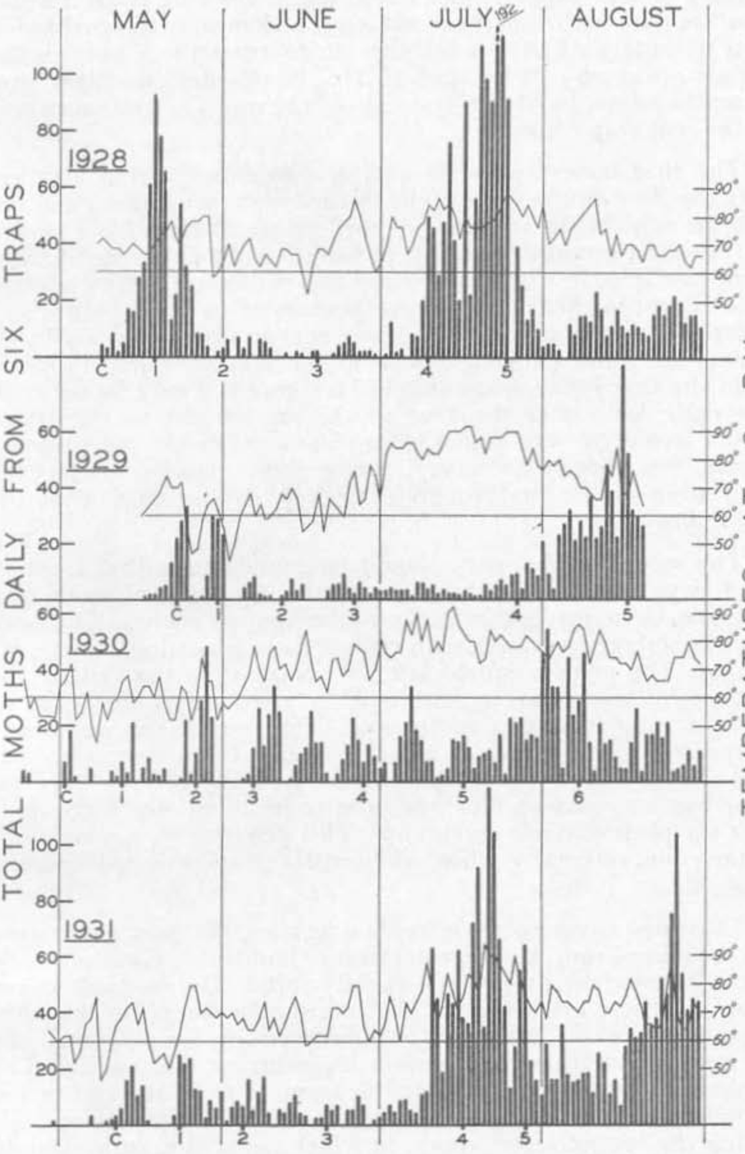

Fig. 2.—Record of codling moths captured in bait traps for four different years at Parma, Idaho. Note that moth populations, as determined by bait traps, were different each year and that spray dates differed accordingly. In a season when broods are not distinct, as in 1930, more cover sprays are required to obtain control, for relatively high moth populations are maintained throughout the season. Spray dates are indicated by the figures at the base of the chart for each year.

orchard. When properly operated, the moth bait traps furnish accurate data as to the moth activity, and inform the orchardist quite definitely when this activity has increased to a point when a cover spray should be applied. He should plan his spray program, therefore, to fit the demands of the moth activity as given by the bait trap record.

The first cover spray should be completed within 10 days after the first moths are caught in the traps in numbers and before the eggs begin to hatch in the spring. Studies have shown that the first brood eggs hatch in from 6 to 13 days, the average being nearly nine days, and when the moths are active enough to be caught in the traps they are also active in egg laying. Eggs in early spring, owing to the lower temperatures, do not hatch so soon as those deposited later in the season, hence the date when the first cover spray should be completed may be set with safety 10 days after the first moths are caught in the traps. Moths frequently are active before the time of the calyx spray. It may, therefore be necessary, during some seasons, to start the application of the first cover spray four or five days after the calyx spray.

The second cover spray should be completed within from 10 to 14 days after the first unless information gained from trap observances indicates that it should be applied sooner. The peak of moth emergence varies with temperature conditions from year to year. The grower must plan his spraying so that either the first or the second cover spray will be effective against eggs or larvae arising from this moth peak. The grower can determine by trap records whether or not the peak of moth emergence occurs after the first cover spray. If it does, he should time his second cover spray application so as to be completed eight days after the peak of moth emergence. This peak spray is a very important one, especially when oil emulsion is used in combination sprays.

The third cover spray is applied against the first generation and benefits from it are sometimes doubtful. Normally the moth population drops off rapidly after the second cover spray but there are always a few late moths emerging throughout the middle of the summer and during some years, as in 1930, the moth population may remain high during that period. The third cover should be completed in from 14 to 18 days after the second unless an abnormally high moth population develops following the second cover spray, in which event this spray should be completed sooner, often 10 days after the second spray. Late emerging summer moths are responsible for the tiny worms in the apples just at harvest and the third cover spray normally is of benefit in reducing these small, late worms.

The fourth cover spray is usually the first spray directed at the second brood. It should be timed so as to be applied within eight days after traps show definitely that moths of the next brood are emerging.

The fifth cover spray should be applied from 10 to 15 days after the fourth, depending on weather conditions. If first-brood moth emergence is very rapid, it should be completed within 10 days.

A sixth cover spray is sometimes advisable when the moth activity starts early in the season and continues to be very pronounced until late in August. In 1932 weather conditions were such that the first-brood emergence followed so closely after the spring brood that five cover sprays had been applied by July 26. Where infestations were severe, a heavy emergence continued through August making a sixth cover spray advisable for protection against late worm injury.

The spray schedule described above is for the lower warmer districts of Idaho. Five or six cover sprays are not necessary in some of the other districts where codling moth control is easier. In these districts, usually the third cover spray and often the fifth and sixth cover sprays may be safely omitted. Timing the other applications is essentially the same as described and it is very important to correctly time the sprays directed against the peaks of both first-brood and second-brood larvae.

Chemically Treated Bands

Chemically treated bands have proven quite effective in killing codling moth larvae and their use is one of the most important supplements to spraying. After larvae have reached maturity they search for a dark, protected place in which to pupate and in doing so many of them crawl up or down the tree trunks where they start to spin their cocoons, under chemically treated bands apparently as readily as under untreated bands or bark. Nearly all of the larvae that spin their cocoons in contact with chemically treated bands are killed. These bands have the advantage over untreated bands in that if they are properly prepared they require no attention throughout the season and, labor considered, they are more economical. Complete information on preparation and use of chemically treated bands is available.[4]

Cold dipped chemical bands have proven very economical and effective in experiments conducted in Illinois.[5] These bands are prepared by dipping the corrugated paper rolls in a cold mixture of powdered crude beta naphthol, 1 pound; mineral oil, viscosity 200-300 seconds, 1½ pints; and gasoline, 1 pint. The beta naphthol in the mixture, as used in the Illinois work, had been finely ground with the oil into a factory product of the correct proportions for dipping. The gasoline is added to thin

4 "Preparation and Use of Chemically Treated Corrugated Bands as a Supplemental Control for the Codling Moth." U. S. D. A., Bureau of Entomology, Cir. E-294, by E. H. Siegler and F. Munger.

5 Chemically Treated Bands, Farrar, M. D., and W. P. Flint. Jour. Econ. Ent. vol. 26, No. 2, 364-368, 1933.

the mixture so that it is suitable for dipping the bands. The experiments cited indicate that incorporating liquid roofing cement, 9 per cent by volume, into the cold mixture increased the kill and that more larvae were captured under the cement-treated bands. On a fairly large scale, cold dipped chemical bands can be made for about 0.7 cents per linear foot for labor and material.

The chemically treated band consists of a strip of corrugated paper two inches wide which has been thoroughly coated with a mixture of beta naphthol and red engine oil of a paraffin base and having a viscosity of 300. Mix the two ingredients together in the proportion of 1 pound of beta naphthol to 1½ pints of oil and heat until all of the beta naphthol has gone into solution. Continue heating until a temperature of 265-270° F. is reached and maintain the temperature within this range throughout the treating process. Immerse each roll of corrugated paper in a position so that the tubes are vertical and so that only half of the roll is in the solution. Allow it to remain approximately one second, then turn it over and immerse the other half. This complete process may be again repeated, producing a double-dipped band. Two-inch corrugated bands should contain not less than 2 pounds of beta naphthol per 100 linear feet. The cost of hot-dipped chemically treated bands two inches wide is about one cent per linear foot. Both beta napthol and oil are inflammable but not explosive and beta naphthol is irritating to eyes and skin. All work in connection with preparing chemically treated bands should be carried on out-of-doors.

Bands should be in place by June first in the warmer parts of Idaho and should not be removed until in the late winter or the following spring. Fresh bands are needed each year. Before bands are applied, the rough bark should be scraped off of the trunks and larger limbs and trash and weeds should be kept away from the bases of the trees. A convenient scraper may be cheaply made by drilling a hole through the center of a mower sickle section and through this bolting an iron handle. The roll of treated corrugated paper must be handled carefully in order to prevent losing some of the chemical material. If the trunk has vertical grooves, the band should first be fitted into the grooves and held there by means of a tack. The rest of the band is then placed around the trunk with the ends overlapping about an inch and held in place by a large headed tack or wire staple. Bands should fit snugly to the trunk.

OIL EMULSIONS

An emulsion consists essentially of a suspension of small droplets of one liquid in another. Mineral oil is very injurious to trees unless the amount of it is exceedingly small. A very small amount of oil cannot be practically applied alone but it can be diluted and used with safety. To dilute oil with water it is necessary first to form an emulsion of oil in water. In this emulsion small droplets of oil are suspended in the water. The size of the droplets depends on the amount and the kind of emulsifier used and the process of emulsification. The emulsifier serves the purpose of coating each droplet of oil with a material that prevents it from running together with another droplet. Thus oil may be applied to plants in almost any degree of dilution. The expressions "quick-breaking" and "stable" emulsions are relative terms applied to indicate the length of time the oils will remain in suspension. In quick-breaking emulsions the droplets of oil are relatively large and the amount of emulsifier very small. They give the highest degree of insect control, but owing to their instability, they are likely to deposit free oil on the foliage sprayed and to cause severe injury under practical orchard conditions. Most of the commercial emulsions now on the market are relatively stable in type.

Home-Made Emulsions

Many growers, and especially the larger operators, may effect a saving in the use of oil by preparing their own emulsions. The emulsions may be made in two ways: the preparation of a concentrated emulsion by the casein-ammonia formula, and the "tank-mix" method.

The concentrated casein-ammonia oil emulsion is prepared according to the following formula, which makes 10 gallons of emulsion containing 80 per cent oil:

Water	2 gallons
Ammonia (concentrated) (28%)	2.4 liquid ounces
Casein (finely powdered)	4 ounces
Oil	8 gallons

Place water in the container and, with the agitator or mixer running, add the ammonia; then slowly mix in the casein. As soon as the casein is dissolved, add the oil slowly, mix for about 20 minutes, and then pump it through a spray hose at about 250 pounds pressure. Larger quantities, such as 50 or 100 gallon lots, may be prepared in the spray tank. Be sure to add the oil slowly. After it is thoroughly mixed, the emulsion may be pumped into steel drums where it may be safely stored for about a week.

The "tank-mix" method has given good results both experimentally and in the field. The amount of oil required for a tank of spray is emulsified each time the tank is filled, and if 1 per cent (1%) oil spray is to be used, one gallon of oil is emulsified or mixed in each 99 gallons of water. First, fill the tank with water to cover the agitator; then with agitator running, add the emulsifier. It is best to mix the emulsifier with a little water before adding to tank. Next, slowly pour the required amount of oil into tank and then fill with water. Apply spray immediately, continuing agitation until tank is empty. A satisfactory emulsifier is a blood albumin-Fuller's earth mixture that is on the market in convenient packages. It is used at the rate of 4 ounces to 100 gallons spray. The "tank-mix" method should be used only with tanks equipped with high speed agitators, or with square-end agitator paddles, since a thorough agitation is necessary for a good emulsion or mixture. When lead arsenate is used, add it after the tank is filled.

Chemical and Physical Properties of Oils Suitable as Insecticides

Lubricating oil, which is the basis of insecticidal oils, is refined from crude petroleum by distilling off the more volatile compounds and by chemical treatment to remove certain objectionable materials. Lubricating oils are of complex and variable composition and, in greater or less degree, contain substances which are harmful to insects or injurious to plants. The degree of insecticidal value and of harmfulness to plants changes, therefore, with the degree of refinement. From the mass of evidence now available, it is possible to select oils for specific spraying purposes. Much confusion exists concerning the chemical composition of lubricating oil but most of the evidence supports the belief that the main constituents are the chemically inert hydrocarbons of the paraffin and naphthene groups which are known as "saturated hydrocarbons." The chemically active hydrocarbons of the olefine and aromatic series, known as the "unsaturated hydrocarbons," while present in lubricating oils in only small quantities, are known to be harmful to green plants and probably are more toxic to insects than the inert hydrocarbons. An insecticidal oil is prepared by removing only enough of the harmful substances so that the oil may be safely used on foliage.

Unsulphonated Residue. Lubricating oils are treated with sulphuric acid to remove objectionable hydrocarbons and then washed to remove the sulphuric acid. The oil remaining is known as the "unsulphonated residue," a term used to designate the degree of refinement that an oil has undergone. The higher the unsulphonated residue, the more drastic the refining. The unsulphonated residue varies from about 50 to 70 per cent for ordinary dormant oils to about 80 to 98 per cent for summer oils.

Viscosity. The "flowing quality" of oil is designated in terms of viscosity. Chemists measure viscosity by allowing 60 cubic centimeters of oil to run through a standard orifice at 100° F. in an instrument called the Saybolt Universal Viscosimeter and the time required for the given volume of oil to pass through the orifice is recorded in seconds. Thus an oil that requires 70 seconds to pass through the orifice is said to be more viscous than one that requires only 50 seconds and the oils would be designated as having viscosities of 70 seconds and 50 seconds. In a general way, the more viscous an oil, the less volatile it is.

Mineral Oil Specifications. Based on the data of experimental work with oil sprays during the past seven years, the Western Cooperative Oil Spray Project, of which the Idaho Experiment Station is a member, has agreed upon definite specifications for mineral oils used in oil sprays. These specifications are (1934) as follows: It is important that fairly close-cut oils be used in the preparation of oil sprays. Blends of extra heavy and light fractions should be avoided. Oils labeled "light," "light-medium," and "medium," and having the approximate viscosities of 52", 63", and 75" Saybolt at 100° F., respectively, should come within the following distillation range specifications:

Light:	65-100% of oil should distil at 636° F.
	Not more than 10% should distil at 520° F.
	Not less than 80% should distil at 665° F.
Light-Medium:	50-65% of oil should distil at 636° F.
	Not more than 10% should distil at 530° F.
	Not less than 80% should distil at 715° F.
Medium:	40-49% of oil should distil at 636° F.
	Not more than 10% should distil at 540° F.
	Not less than 80% should distil at 725° F.
Dormant Oils:	Sulphonation test, 50-70.
	Viscosity, 100 to 120 seconds.
Summer Oils:	Sulphonation test of not less than 85.
	Viscosity, 65 to 75 seconds.

Fish Oil Specifications.[6] Fish oil used in codling moth sprays should be perfectly clear and remain liquid at 65° F. and should be slow drying, with an iodine number between 120 and 145. Pacific Coast herring oil or dogfish oil meet these requirements.

SPRAYING EXPERIMENTS IN IDAHO[7]

The Idaho Agricultural Experiment Station began in 1927 a series of experiments calculated to determine the best and most economical means of codling moth control under Idaho conditions. The experiments were continued through the year 1931. From year to year materials or combinations found to have merit were tested and those which were proven to be ineffective were eliminated from the tests. Codling moth activity and the timing of spray applications in the experiments are shown graphically in Fig. 2 for four of the designated years. Preliminary work with oil emulsion sprays was undertaken in 1926, and most of the work in 1927 was with oil not used in combination with other insecticides. Experimental plots in 1927 were located in the J. P. Gray Orchard, Nampa. Experiments from 1928 to 1931, inclusive, were conducted in orchards of the Roswell Park Orchards Co., Parma, Idaho.

Summary of Results, 1927[8]

Oil emulsion sprays alone gave a high degree of control throughout the season when substituted for certain lead arsenate

6 Suggestions for the Use of Oil Sprays in 1934. Report of the Western Cooperative Oil Spray Project.

7 Extensive tables detailing the materials used and the results obtained have been omitted from this Bulletin. Individuals especially interested in the tables may obtain a mimeographed copy upon application.

8 "Sound Fruit" as used in the summaries for the years 1927-32 means fruit free from both worms and stings.

sprays. One and one-half gallons of oil per 100 gallons of spray solution produced, on the average, more sound fruit than when only ¾ gallon was used. The quicker breaking emulsion prepared with 1½ ounces of calcium caseinate to 2 gallons of oil gave a higher degree of control, in general, than the slower breaking emulsions prepared with 3 ounces of calcium caseinate when oil emulsion was used without lead arsenate. Other arsenicals were inferior to lead arsenate. The use of lead arsenate, 3 pounds per 100 gallons of water, resulted in 98.20 per cent of sound fruit as compared with 95.48 per cent of sound fruit when 2 pounds of lead arsenate were used. The use of Blackleaf 40, 1 pint, and oil, ½ gallon, to 99 gallons of water, substituted for lead arsenate in the last three cover sprays, resulted in 98.09 per cent of sound fruit. When Blackleaf 40 was substituted alone for lead arsenate in the last three cover sprays, 89.08 per cent of sound fruit was produced. The initial infestation was low, as was indicated by the fact that the unsprayed check produced 42 per cent of sound fruit, so a higher degree of control was obtained with from one to two less sprays than in the experiments of the following years.

Summary of Results, 1928

Following the experience of 1927, oil sprays, not in combination with other insecticides, were tested again. A low degree of control was obtained with oil emulsions alone at both ¾ gallon and 1½ gallons per 100 gallons of spray. The use of lead arsenate at the standard recommended strength of 2 pounds per 100 gallons water resulted in 79.36 per cent of sound fruit produced. When lead arsenate was increased to 3 pounds per 100 gallons, 88.36 per cent of the fruit was free from injury. No. 4 oil (unsulphonated residue 90, viscosity 50 seconds) proved to be very much less effective than No. 3 oil (unsulphonated residue 95, viscosity 104) at both strengths tested. No. 4 oil at 1½ per cent strength was considerably more effective than at ¾ per cent. No. 3 oil, however, was nearly as effective at ¾ per cent as when the amount was doubled. Adding oil emulsion to lead arsenate cover sprays increased the percentage of sound fruit from 79.36 per cent to 92.14 per cent. As in 1927, Blackleaf 40, 1 pint, in combination with ¾ gallons of oil per 100 gallons of spray in the last two cover sprays, proved more effective in control than lead arsenate alone; the respective amounts of sound fruits being 84.61 per cent and 79.36 per cent. Blackleaf 40 alone, 1 pint in 100 gallons spray, in the last four cover sprays, produced only 69.88 per cent of sound fruit, whereas when it was used in combination with oil emulsion the percentage of sound fruit was 91.67.

The degree of control was much less throughout the year than in 1927 due to the season being one more favorable to codling moth activity and to the orchard carrying a higher initial population as indicated by the fact that only 10.34 per cent of the fruit on the unsprayed check escape codling moth injury.

It was quite difficult to remove arsenic from fruit that had been sprayed with No. 3 oil, and almost impossible to reduce the residue sufficiently to meet the requirements of the Federal Food and Drug Administration. Furthermore, the No. 3 oil caused slight injury in the stem cavity of Rome Beauty apples that was not evident when No. 4 oil had been applied.

Summary of Results, 1929

No. 6 oil (unsulphonated residue 90, viscosity 75) was substituted for No. 3 oil since it was less highly refined and consequently less expensive, and was lower in viscosity, favoring easier removal. Because of the unsatisfactory results obtained with oil emulsions alone in 1928, they were used only in combination with other insecticides. No. 6 oil proved to be the most effective of the oils when used at ¾ per cent strength, and it was very nearly as effective at that strength combined in all lead arsenate cover sprays as when the amount was doubled, the amounts of sound fruit produced being 93.31 per cent and 93.97 per cent. The effectiveness of lead arsenate was increased from 78.54 per cent to 85.36 per cent by increasing the dosage from two to three pounds per 100 gallons water. Oil added to lead arsenate materially increased the degree of control. Oil, ¾ gallon, added to 100 gallons of lead arsenate in the peak sprays for both first and second broods, produced nearly as good results as when it was added to all of the cover sprays, the amounts of sound fruit being 94.39 per cent and 93.31 per cent, respectively. The highest degree of control, 95.26 per cent, was obtained by the addition of 1 quart of fish oil per 100 gallons of spray to all lead arsenate cover sprays. When Blackleaf 40, 2/3 pint, and oil, ¾ gallon per 100 gallons of spray, were substituted for lead arsenate alone in second-brood cover sprays, 92.45 per cent of sound fruit resulted.

Summary of Results, 1930

Results with lead arsenate at different strengths were inconsistent with and contradictory to those of former years. For example, 92.90 per cent of sound fruit resulted when lead arsenate was used at the rate of two pounds per 100 gallons of water. When the dosage was three pounds, 90.78 per cent of sound fruit was produced. Addition of oil to the regular lead arsenate cover sprays increased the degree of control in all tests. The degree of control was greater with No. 6 than with No. 4 oil. When ¾ per cent No. 6 oil was used in the two peak sprays in combination with lead arsenate the degree of control (96.15 per cent) was nearly the same as when ¾ per cent No. 4 oil was used in combination with lead arsenate in all cover sprays (97.18 per cent). Blackleaf 40, 2/3 pint, and oil, 0.8 gallon per 100 gallons spray, produced 93.40 per cent of sound fruit when substituted for lead arsenate in late cover sprays; whereas the degree of control with lead arsenate was 92.90 per cent. Fish oil, 1 quart per 100 gallons of spray, added to lead arsenate in all cover sprays, did not produce a higher degree of kill than lead arsenate alone, the sound fruit produced being 91.89 per cent and 92.90 per cent, respectively.

Summary of Results, 1931

Experiments in 1931 were planned mainly to try again some of the most promising materials tested in former years and to endeavor to establish practical, economical procedure. It was found that oil added to the first two lead arsenate cover sprays produced nearly as good control (94.27 per cent) as when it was added to the two peak sprays (95.55 per cent). Subsequent tests indicated that arsenical residue is readily removed from fruit sprayed with oil and lead arsenate in the first two covers. Fish oil added to all cover sprays of lead arsenate did not increase the degree of control, the amounts of sound fruit being 90.29 per cent and 93.03 per cent, respectively. Blackleaf 40, 2/3 pint, in combination with oil, 0.8 per cent, substituted for lead arsenate in the late cover sprays, resulted in 93.75 per cent of sound fruit; whereas lead arsenate produced 93.03 per cent of sound fruit.

CONTROL RECOMMENDATIONS

Codling moth infestation in Idaho varies in intensity in different districts, orchards, or even in portions of the same orchard. Severity of infestation varies from year to year and depends on temperature at the time of moth emergence, length of growing season, and degree of infestation the previous year.

Within a single district, orchards vary in exposure, density of tree growth, type of cultivation (whether cover crop or clean), and type of soil. These factors affect the time and duration of emergence and the development of the codling moth. Because of these variable factors, specific spray recommendations cannot be made for an entire state or district. The spray program, while based on general principles, must be worked out in detail by the grower for each individual orchard in addition to depending on district spray dates set by horticultural inspectors.

On the basis of experimental work for codling moth control which has been conducted for five years, and on its application to commercial orchards, the following conclusions have been deduced:

Spray Materials

Lead arsenate is the most important single insecticide for codling moth control. Its use is recommended in all cover sprays. Two pounds to 100 gallons of water are usually sufficient when spraying is thoroughly done and applications are properly timed. For heavy infestations or unusual conditions three pounds are recommended. Spotting of fruit is eliminated and residue removal is facilitated by the addition of colloidal or soap spreaders, or fish oil, to lead arsenate sprays.

Summer oils used alone do not result in a high degree of control of the codling moth. Oil should be used only in combination with lead arsenate or lead arsenate substitutes at the rate of one gallon of oil emulsion to each 100 gallons of spray solution. Effectiveness of oil depends on its egg killing power. It is most valuable, therefore, if applied at the peak of the egg-laying period. The peak of egg laying of moths producing second-brood larvae so often comes late in the summer that it is considered impracticable to use oil with lead arsenate for second-brood larvae since the late use of this spray combination renders residue removal extremely difficult.

The number of applications of summer oil should not exceed two, and these are most effective when added to the first two cover sprays. One gallon of commercial oil emulsion to 99 gallons of water is sufficient. Close-cut oils ranging in viscosity from 65 to 75, with a sulphonation test of not less than 85, have proven the most satisfactory. Dormant type oils complicate spray residue removal and are likely to cause injury if applied as summer sprays.

The use of nicotine sulphate (Blackleaf 40), 2/3 pint, and oil emulsion, one gallon to 100 gallons of dilute spray, is about equally as effective as lead arsenate and this combination may be substituted for lead arsenate, if desirable. However, the sulphate is very much more disagreeable to use and much more expensive than lead arsenate; facts which will probably prevent its becoming a widely used substitute. Furthermore, the nicotine-oil combination following lead arsenate renders residue removal difficult.

Better control of the codling moth has resulted in some experiments from the addition of one quart of fish oil to 100 gallons of lead arsenate spray, but in general, it has not increased the degree of control in Idaho. However, fish oil used with lead arsenate has been found by the Washington Experiment Station to be satisfactory in the control of the codling moth. If it is added to all cover sprays, the amount used in 100 gallons of lead arsenate spray should not exceed 1 pint. One quart per 100 gallons may be added if it is used in only two applications. Fish oil may cause injury unless these precautions are observed.

Spray Applications

The calyx spray should be applied when about 90 per cent of the petals have fallen and before the calyx lobes have closed. Use lead arsenate at the rate of two pounds in 100 gallons of water. This spray should never be omitted.

Cover sprays should be timed carefully by the use of bait traps placed well up in the trees, away from packing sheds or other buildings. The first cover spray should be completed within 10 days after moths begin to appear regularly in the bait traps. The second cover spray should be completed within 10 to 14 days after the first. Because of the variability of the peak of larval emergence from year to year, it is recommended that oil emulsion, one gallon per 100 gallons of spray, be added to both the first and second cover sprays in order to be certain that the oil will be applied to the eggs at the most effective time. In some localities and during some seasons, it is necessary to apply a third cover spray for the first brood. This should be timed from 10 to 18 days after the second cover spray, depending on moth activity.

The first cover spray for second-brood larvae should be completed within eight days after moth traps show a marked increase in the number of moths captured after July 1. A second cover spray for the second brood, when needed, should be completed within 10 to 15 days after the first second-brood spray, the interval elapsing depending on weather conditions. If a third cover spray for second brood is necessary, it should be completed within another 10 days.

The need of thoroughness in spraying cannot be over-emphasized. Every portion of the tree must be covered. Special attention should be given to the tree tops and trees should be sprayed from the interior as well as from the outside. It is economy to use plenty of liquid. Twenty gallons of liquid or more may be required to completely spray a twenty-year-old tree. Spraying equipment should be kept in prime condition so that a pressure of at least 350 pounds may be maintained. It is extremely important to have equipment sufficient to insure covering the entire orchard in not more than three or four day's time.

Supplemental Aids to Spraying

Sterilize all boxes or place them within the packing shed which has all doors, windows, and other openings tightly closed during the spring and summer in order to prevent escape of moths that emerge. Avoid transportation of infested apple boxes from one orchard to another.

Scrape rough bark from tree trunks and large limbs in the early spring to destroy overwintering larvae. This should be done to a depth of one or two inches below ground. Band the scraped trees June 1, using chemically treated bands, and do not remove the bands until late winter or the following spring.

Thin the fruit to break clusters, since worms enter more readily at places where apples touch. When thinning, remove and destroy wormy fruit. Destroy cull apples to prevent larvae in them from escaping.

Spray Residue Removal

Apples sprayed in accordance with the recommendations outlined in this bulletin can be sufficiently cleaned of arsenic and lead residue to permit their sale in the United States or foreign markets if the following suggestions of the Idaho Agricultural Experiment Station are followed [9]:

1. The removal of the spray residue should be considered by the grower at the very beginning of his spray schedule. Keep accurate records of all materials used and number of applications made. Use the following precautions when oil is necessary for codling moth control:

   a. Do not use oil with a viscosity above 65 to 75.

   b. Do not make more than two oil applications during the season.

   c. Do not apply oil with, or over, lead arsenate for second brood sprays.

2. Pick the apples as soon as they are ready and wash immediately. If immediate washing is impossible, place the fruit in cold storage at once and hold until washing can be done. Fruit held in common storage or fruit left standing at ordinary temperatures for a period of time develops a coating of wax that makes residue removal difficult.

3. Use hydrochloric acid at a strength of 1 to 1.6 per cent (three to five gallons of commercial hydrochloric acid to 100 gallons of water) or sodium silicate at a concentration of 60 to 90 pounds per 100 gallons for the wash solution. Fruit sprayed with fish oil can be cleaned more easily with sodium silicate than with hydrochloric acid. When fruit is difficult to clean the washing efficiency is increased by adding soap to sodium silicate solution, or vatsol to the acid solution. Sodium silicate followed by hydrochloric acid is required to clean the more difficult lots of fruit.

4. Heat wash solutions to a temperature of 95° to 105° F. for early maturing fruit. For late fruit the temperature may be increased another 10 degrees. With machines holding the fruit in the wash solution for over 40 seconds, the temperature must be kept lower to avoid injury. Immature and less resistant varieties of fruit also require lower temperatures or shorter periods of exposure.

5. Washing machines should be adapted to hold the foam produced by the silicate-soap wash or the acid-vatsol wash, as the foam is important in increasing washing efficiency.

6. Rinsing is one of the most important processes in the washing of apples and should be done very carefully. Use a large quantity of running water. A final rinsing of the apples

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[9] Recommendations on Residue Removal, prepared by H. P. Magnuson and Robert S. Snyder, Dept. of Agricultural Chemistry, Idaho Agricultural Experiment Station.

should be made with a diffused spray of water as they are leaving the bath.

7. Remove all decayed or injured fruit before the apples are washed. This eliminates all unnecessary contamination in the wash tank or rinse solution. Care must be exercised in the handling of the fruit. Bruises or injury offer opportunity for decay.

8. Use utmost care in the handling of hydrochloric acid as it is very harmful to metals, clothes, and body. Check the strength and temperature of all wash solutions frequently.